A. J. Johnson

VICTORIAN HILL AND DALE

The Barwon, near Geelong.

VICTORIAN HILL AND DALE

A Series of Geological Rambles

BY

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PREFACE.

LIKE many other things in this world, these sketches have grown. In 1899 I wrote an account of the geology of Melbourne for the Handbook of the Melbourne meeting of the Australasian Association for the Advancement of Science, which took place early in the following year. Then followed several popular lectures on the same subject, and in the summer of 1905–6 I contributed, under the name of "PHYSICUS," a series of geological articles to the Melbourne *Argus*. These I have here republished, with a few alterations, and I desire to thank the proprietors of that journal for their kind permission to use them again. A few additional chapters have been added, in the hope that they may be of some interest, and even value.

T. S. H.

June, 1909.

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CHAPTER I.

The Rocks of Beaumaris.

The seafront from St. Kilda to Mordialloc, with its stretches of sandy beach separated by rocky points, is Melbourne's favourite picnic-ground. Wherever the native vegetation has been preserved, and the shore is backed by cliffs, ideal camping-grounds are abundant, and are fully availed of throughout the summer.

The superficial aspects of this strip of country have frequently been written on, for its flowers, shrubs and birds have a charm that is self-evident. All these things, animate or inanimate, are merely one expression of the structure and composition of the rocks which form the land. To realise this, we have but to glance at the coast from Williamstown, south-westerly. Between the two types of country there is a marked contrast in every way. The one is richly clothed with hosts of flowering plants, alive with insect and bird life, full of the charm of variety; the other is a monotonous, grass-covered expanse, with a beauty of its own, it is true, but sameness is its keynote. The explanation of these differences is supplied by the geologist, and we may listen to what he has to say.

1.—Red cliffs at Beaumaris, with tea-tree growing along the top.

An examination of the cliffs along the Sandringham Coast shows that they consist, in the main, of sand, composed of grains of quartz. In places the sand is cemented into a more or less compact rock by an admixture of clay and red iron-rust. Wherever this hard rock occurs, we have a beach of ironstone shingle, and this shingle occurs on every point from St. Kilda as far as Mordialloc. Shingle is less easily moved by the waves than sand is, and in the comparatively quiet waters of the bay is not carried far from its place of origin. We can readily see that the loose stones are merely broken up pieces of the cliffs, which the restless waves are for ever beating against, and wearing away. But the shingle forms a barrier which protects the foot of the cliff, so that the inroads of the sea are to some extent held in check, and the little capes and points occur just where the

shingle banks are seen, because here the rocks are harder. It may be pointed out that "rock," in the geological sense, is a term applied to any solid material forming the earth's crust. So that hard stone is rock, and so is soft mud or loose sand. Wherever the red rock is absent, the more loosely compacted beds fall a ready prey to the inland march of the waters.

Nowhere is this better illustrated than in the neighbourhood of Beaumaris. Rickett's Point is a mass of ironstone, against which the sea has comparatively little power. Then comes a change in the direction of the coast-line, and the head of the Beaumaris Bay is backed by vertical cliffs of almost unconsolidated sand, which fall at every storm, and the fallen masses are rapidly broken up and carried away by the waves If we look at the red rocks anywhere about Black Rock or Quiet Corner, we see that they lie in horizontal sheets, and this is true of almost the whole of the red rocks about Melbourne. But in one or two places among the cliffs, to the east of Beaumaris Hotel, and near Charman's-road, the beds are steeply inclined for a short distance. This rapidly brings the hard rock below sea-level, the soft upper rocks reach the shore, and the Beaumaris-Mentone Bay is the result, for the upper part of the cliffs almost everywhere consist of loose sand. Why this is so we shall see later.

The horizontally-bedded sandstones throughout the district have evidently been laid down under water. Wind will distribute sand over the country, but the layers are never so evenly spread as they are by

water. Besides this, in many places there are fairly large quartz pebbles present, and whole beds of sand occur which are far too coarse to be drifted by air currents. There is, besides, another fact. In the cliffs, about Beaumaris especially, we find fossil shells of various kinds embedded in the rock. Almost at the small point a hundred yards west of the boat-house, is a white seam of shells, which can be traced for some distance. In some places are layers of sea-urchins, or sea-eggs, and sharks' teeth are often washed out of the beds and lie loose on the beach. These are all the remains of sea-dwellers, and show not only that the layers of sand were laid down under water, but under sea-water, and that each successive sheet once formed the surface of the sea-floor. Very few of the fossils belong to living species, nearly all are extinct. Measured in years, of course, the beds are very old, probably scores of thousands of years, but geologically they are young, though not the youngest of the beds found near Melbourne,

The source of the materials which have accumulated in the vast sheets whose edges are visible in the cliffs lay inland. The dry land is subject to continual waste—rain and wind, heat and cold, all unite in rasping down whatever stands above sea-level, and the ultimate resting-place of this material is the sea. Here it is that accumulation takes place—here we find the "dust of continents to be." The water classifies the sediments; the finer they are the further they are carried, the heavier and coarser the sooner do they come to rest. The rocks of the Brighton coast are fairly coarse-grained; they are gravels and sands

2.—Beaumaris Bay. The red sands of the cliffs on the right pass under the white sand cliffs in the distance. These, offering less resistance than the red cliffs to the waves, have been cut back and the bay formed.

This material has not travelled very far, and the fine muds have gone farther out to sea.

We must look to the highlands of the Dividing Range as their source, and here we find ancient sandstones and granites which will yield all we want. The red rocks are a measure of the waste that has taken place in the past ; the coarse sands are the concentrates, as miners would say, and represent a much vaster bulk of broken-down older rocks, for the fine muds and clays have been carried elsewhere.

But the rocks are red and brown, stained by Nature's great pigment, iron. Older than the red-rocks, there were poured out in various places in the neighbourhood large sheets of bluestone and similar rocks, rich in iron, and affording by their waste probably the greater amount of the colouring matter the sandstones now contain.

But the cliffs can tell us another series of facts of a different character. Walking or driving anywhere about Brighton or Cheltenham, we notice that the country is covered in most places by white sand, not by red rock. An examination of the cliff, say, at Beaumaris or Half-Moon Bay, shows that there is a three-fold division in the rocks. There is an upper division consisting of white sand, a middle division in which iron is very abundant, and at times collected into nodules, which afford all sorts of curiosities to the imaginative, such as umbrella-handles, teapot-spouts, mushrooms, human heads and limbs, and, in fact, anything you like to ask for. They are not fossils, but merely masses of iron rust, which have collected into these forms by what is vaguely described

as concretionary action. To most people they are more wonderful than are the real fossils themselves.

At a lower level than this layer with concretions, we find the third division, consisting of massive, well-bedded rocks, stained a uniform brown, and with no excess of iron to form concretions. We have then an upper layer devoid, or almost so, of iron; a middle layer, with more iron than it should have, and a basal layer, with only its original amount of iron. With the exception of the amount of iron present, there is practically nothing to distinguish the beds at the top of the cliff from those at the bottom. They are one series, and owe their origin to the one set of causes. But something has dissolved out the iron from the upper part, and redeposited it in the middle layers, while the lower layers are practically unacted upon. It must have been an agent capable of dissolving such a substance as iron oxide, or iron rust, and yet one which, by a slight and rapid change, would become unable to retain the iron in solution, and so had to redeposit it in the concretionary middle series.

Such an agent is readily found. The plants which clothe the soil do not accumulate there indefinitely. When they die they decay. If this decay did not take place the surface of the ground would be covered by a thick layer of dead vegetation. All the plant-food would be locked up, and all life would cease. For the succession of life to be maintained, it is essential that decay should take place; the old accumulations of food must be released, and made available for new growths. The duty of bringing

about this decay is that of bacteria, and without their aid in this way, all life would rapidly come to an end. But decay is a complicated series of changes, and during the process certain acids are formed. If they accumulate, as they do in peaty soils, the ground becomes what the cultivator rightly terms "sour." Usually, however, the acids are washed deeper into the ground, and on their way they dissolve pretty nearly anything they meet with. In this manner the iron is removed from the upper layers, and only the white almost insoluble sand is left. But the acids themselves are only a stage in the process of decay. They in turn gradually change; they absorb oxygen, and turn at last into carbonic acid, and can no longer retain the bulk of the iron, which deposits as iron oxide; and so the concretions grow.

Below the concretionary layer, the acids have, in the main, lost their solvent power, and the rocks are comparatively but little altered. To this cause, then, is due the white sand that covers all the country about Sandringham and Beaumaris, the heath land of our south-eastern suburbs. The heath-land carries its own peculiar set of trees and shrubs, and harbours and feeds its own series of insects and birds, and we have a harmonious whole, self-contained and self-supporting, and distinct from that found on soils of another character and origin.

We need a comprehensive name to apply to these beds. Geologists have one, but it refers to their age, and to use it would cause difficulties. About Beaumaris the rocks are usually red in colour, and are generally compact sandstones, but they may be white,

loose sands, as we have seen. In other localities, as we shall see later, the same set of beds may include gravels and clays, or even limestones. It will, however, be convenient to call them all "Red-sands" or "Red-beds." In so doing it will be recollected that the term is used as a name only, and not as a definition, and in this sense it is employed as the title of the following chapter.

CHAPTER II.

The Red Sands.

In the foregoing chapter a description was given of the sandy cliffs of Sandringham and Beaumaris, and from the reddish brown colour of the strata composing them the name "Red-beds" was applied. We saw that in that neighbourhood they had been laid down as a series of flat sheets on the sea bottom, and had subsequently been raised to their present height above the waves. The upper parts of the beds almost everywhere are bleached by the removal of the iron-stain by the action of the acids produced by decaying vegetation. The consequence of this is that wherever the "Red-beds" form the surface of a district the soil is usually very sandy. We may state this in the converse way, and say that wherever we find a similar sandy soil in the neighbourhood of Melbourne we can infer, with a fair approach to

truth, the presence below of unaltered red rocks similar to those of Sandringham. Excavations, such as railway or road cuttings, and the recent sewerage works, often show that such an inference is correct, and that the wide distribution of the "Red-beds" may be easily traced in this way.

The most northerly point on the shore at which evidence of the existence of these rocks may be seen is in the neighbourhood of the Middle Park baths, where a red-sandstone shingle occurs on the beach. A small outcrop also occurs at Kenney's baths, under the bridge leading out to the old ship. The Red Bluff takes its name from these rocks, and they may be traced from there almost without intermission as far as Mordialloc. Inland from St. Kilda we find the hill in the Domain, on which Government House and the Observatory stand, consisting of similar strata, and their character may be seen in an excavation between the Observatory and St. Kilda-road. A similar excavation is to be found in the Botanical Gardens, at the top of the hill, near Anderson-street. In fact, the whole of the South Yarra Hill is capped with these sands and gravels.

All the country for a long distance on both sides of the Dandenong-road, as far out as Dandenong itself, is of a similar character. Malvern and Toorak tell the same tale of the presence of a cap of red sands lying on the hill tops. Northwards, after crossing the Gardiner's Creek valley, we see the same sandy soil about Auburn, Camberwell, and Kew. Then comes the interruption of the Yarra valley, but on crossing it we again meet red sands at Preston

and Upper Heidelberg. Still further north we can trace the beds till we come to the flanks of the Plenty and Dividing Ranges.

Everywhere the characters are almost the same, with one important exception. In the neighbourhood of the present coast marine fossils are of constant occurrence, as at Beaumaris, in the railway cuttings at South Yarra and Windsor, and in innumerable road cuttings about Brighton, at Murrumbeena, and even further east on the lower lands. As we pass inland we lose these fossils, and gravels become commoner, mingled with the sands. We seem to have passed beyond the old shore, and to meet strata that have been spread out over the land by a number of shifting streams. The whole series is, in fact, one of old river deposits, hurried down from the highlands to the north. Originally it must have formed one vast plain, sloping gradually southwards, and dipping out beneath the sea. Such plains formed in this way are common enough elsewhere, and the name "coastal plain" is applied to them, though strictly it is confined to that part formed beneath the sea.

All land surfaces are constantly being attacked and worn away by wind and rain, and the surface of a coastal plain such as this is no exception to the rule. As long, however, as the supply of fresh material from the northern highlands was greater than could be removed, the deposit increased in thickness. Gradually the conditions changed. The enormous amount of material brought down from the mountains appreciably lessened their height, while the increased thickening of the coastal plain

3.—Cotham-road, Kew, showing the level coastal plain.

deposits raised that of the land to the southward. The whole slope of the country, from north to south, became more gradual, and the rate of river flow decreased. Material could no longer be brought down in sufficient quantities, and the growth in thickness of the coastal plain ceased.

Then came a period of elevation of the land. Beds containing marine fossils were lifted up above sea level to the positions in which we now find them.

The coastal plain now entered on another stage of its history. The uplifting of the land increased the rate of the streams flowing over it, and so they became able to sweep away coarser material as they ran. They deepened their beds and widened their valleys, cutting easily through the soft sandy strata which formed the plain. Their changing courses wandered now here and now there, as they swung from side to side in their course.

Looking westward from Studley-park over the broad Yarra Valley, we see its opposite edge flanked by the plain from which rise the Exhibition dome and the buildings of the University. Further north stand up the chimneys of the Brunswick brickworks, and the same plain, gradually rising as it goes, sweeps still further north through Preston, till we lose it at the foot of the Dividing Range. It has the same sandy character throughout, for it is all part of the great coastal plain.

The Yarra has cut its wide valley through this sheet of sand down and into the old bed-rock. Here and there we find a trace of the "Red-beds," left as a capping on an isolated hill, which stands up

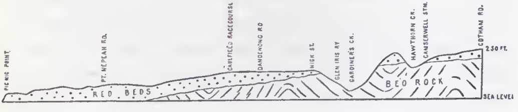
as a measure of the amount of material removed. The Northcote Hill and that on which Christ Church, Hawthorn, stands are examples of such gravel-capped heights. The amount of denudation, as this process of removal is called, is even more extensive as we pass up the Yarra Valley.

About Box Hill, again, scarcely a trace of the beds of the coastal plain is left. The whole district for miles has been "ground-sluiced," as the gold miners say, till nothing but the bed-rock appears. Still, a few gravel-capped hills stand up to show us that even here the "Red-beds" once lay like a mantle over everything, and that, where are now hills and valleys, there was once at a higher level a wide-spread, sandy plain, probably heath-covered, like that at Sandringham.

To a geologist there are perhaps few more impressive views about Melbourne than those from Doncaster Hill. It stands alone, rising high above the surrounding country. To the north-east and north we look down over a maze of hills and gullies to the Yarra Valley, beyond which rise higher hills, which are spurs from the Great Divide. To the south-west the highest land we see is the sand-capped hill on which the Surrey Hills reservoir is placed. South and south-east of us, and still below us, hills and valleys stretch for miles. But Doncaster Hill itself has on it a thick capping of bright-red sands and gravels, the only relic for miles of the old coastal plain. All around every trace of the red sands has been washed away, and nothing but the bed-rock is to be found beneath the soil-cap.

The wide extent of the denudation here, and the amount of material which we can see has been swept away, fairly make one gasp. And yet this great excavation is geologically a thing of yesterday—a work that is even now in the doing.

Two other areas, where a considerable amount of denudation has taken place, may be glanced at. One is the broad flat valley up which the railway from Hawthorn to Camberwell runs. The little creek, with its many branches now straitly confined within masonry walls, has done a lot of work here, and has cut down to bed-rock.



4.—Section from Picnic Point, Sandringham, to junction of Cotham and Burke roads, Kew. This shows what we should probably see if a cliff-face extended all the way. The sloping surface of the coastal plain formed by the red sands is cut into by Gardiner's Creek and by Hawthorn Creek, so that the bed-rock is exposed in their valleys. The heights are exaggerated.

The other instance is Gardiner's Creek, with its tributaries. The flat-topped hill of Malvern and Toorak is only a few feet below the heights of Camberwell and Kew, but it is a stiff climb for a cyclist to go from Malvern or Caulfield to Camberwell, crossing the valley cut out by the tiny stream.

Looking broadly at the whole district on the eastern side of Melbourne, from the mountains to the sea, we can gather that a once continuous layer of sands and gravels of river-borne origin formerly

covered everything; that owing to elevation of the land the cutting power of the streams was revived, and they began to destroy what they had for so long a time been building up. The "Red-beds" began to be eaten into, and their substance once more to be carried seaward. In the lower lying districts, about Caulfield and Cheltenham, no deep valleys could be formed, for streams cannot cut below the level of the sea they discharge into. Here then the original plain-like character is but little changed. Northwards in higher ground deeper valleys formed, and tributary streams worked over the surface till, over large areas, almost every trace of the "Red-beds" was removed. The streams rasped their way still deeper and cut into the underlying bed-rock itself, carving valleys and moulding hills till they gave us the varied land-surface of to-day.

A plateau, or high plain, which has been cut into in this way, is called by geographers "dissected." The constant cutting tends to widen the valleys, to reduce the angle of their slope, to destroy the plain-like character of the high land between two neighbouring streams, and to leave only narrow, undulating ridges, and even these with lapse of time will disappear.

A very large part of Victoria is occupied by such more or less dissected plateaux; sometimes their story is easy to read, but at other times the operations are on so vast a scale, as in the Alps or Otways, that the origin of the scenery is not so evident, and the relics of the former plateau are not so readily traced.

CHAPTER III.

The Bluestone Plain.

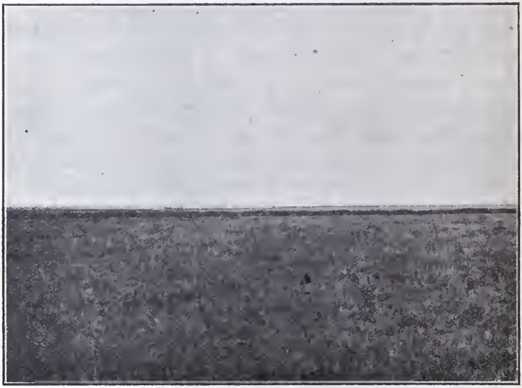
Eighty years ago on their journey of exploration from Sydney to Victoria, Hovell and Hume, when nearing the southern coast kept to the eastern side of the country through which the Melbourne to Sydney line now runs, and got into the difficulties about Mount Disappointment; then, seeing plains to the westward, they made their way towards them, and, passing over the sites of Bulla and Keilor, they missed the Yarra and the site of Melbourne, and at last reached the sea, near Geelong.

They were thus the first white men to travel over the great plain which sweeps up from Port Phillip to Sunbury, and continues southwards to Corio Bay. They saw the country early in December, before it was parched by the heat of summer, and when it was still in its natural state, covered by a rich growth of grass, and gay with low-growing flowering plants in full bloom. The only trees were a few scattered she-oaks, while bushy shrubs were absent, except in a few deep hollows along the streams.

The contrast between this open country and the tree and shrub covered sandy plain to the east of Melbourne, is remarkable, even when we consider the plant and animal life only, and just as striking when we consider the rocks of which both plains are built.

To the east of Melbourne we see an old coastal plain, formed of sands and gravels, brought down by streams from the Dividing Range to the north

This old plain, rising from sea level as we pass north, has been deeply cut into by streams, till, without a little attention, its true plain-like character is apt to pass unnoticed. On the western side of Melbourne the level nature of the country is recognised in popular language by the names Keilor and Werri-



5.—View on the Keilor Plains, showing grass land and wall made of bluestone blocks gathered from the surface of the ground.

bee plains. The sands of the east are replaced by the bluestone of the west ; a level expanse, due to the spreading out of rock-waste by water action, is replaced by one formed by the pouring out of molten lava.

Lava is a loosely-used word applied to a once molten rock, which has flowed over the surface of

the ground, and which may vary very much in its chemical composition and physical structure. The lava of the Keilor plains, or bluestone, as we Victorians call it, is a heavy, dark-grey rock, the other characters of which we shall return to later. It is frequently spoken of as volcanic, and geologists are often asked to say what hills represent the source of the flow. This it is not easy to do, as there are no very prominent ones on which we can fix. Very often lava wells forth very quietly from below, and there are no explosive splutterings to build up a cinder cone round the vent. There are dozens of low, dome-shaped lava hills to the north-west and west of Melbourne, which might quite easily have given rise to a series of lava-flows, separate at first, but finally uniting in one broad flood, which filled the valleys and spread over a wide extent of country, leaving here and there the tops of some of the higher hills standing like islands above it. The Northcote hill and Clifton Hill are good examples of this feature.

We can see in many places that the land surface which was levelled off by the bluestone was very uneven. At the Hawthorn railway-bridge the old bed-rock comes more than half way up the cliff on the Melbourne side of the river, and the lava sheet is thin. Near the Burnley station a deep quarry-hole shows 50ft. or 60ft. of bluestone. About Keilor we find the same thing illustrated again and again. Here we see, along the Saltwater and its tributary gullies, in one place an old ridge and in others a former valley a couple of hundred feet deep, and all levelled off by the flow of molten rock.

The high land to the east of Melbourne ends along a line running through Whittlesea, Alphington, and Kew, and this barred the further eastern extension of the lava. West of this line lies the great volcanic plain of Victoria, sweeping past the foot of the You Yangs, and out through the Western District beyond Hamilton almost to the banks of the Glenelg.

Those who have seen lava actually flowing describe the top and front of the stream as cooling into a hard crust, beneath which the rock is still fluid. The consequence of this is that along the edge of the flow, where its abuts on higher land, there is usually a depression partly filled with cinder-like fragments. Such a depression must have been left along the edge of the eastern high lands, and this would afford a natural place for the new rivers to flow in. This is the reason why, except in a couple of places, we find no bluestone on the eastern side of the Yarra in the neighbourhood of Melbourne. There is one small patch on the Hawthorn side, where the gully coming down from Auburn enters the river near the Swan-street bridge. The river found it easier to cut its way through the softer bed-rock rather than through the more resistant lava, so it worked closer and closer to the high land till it cut the cliffs we see about Kew.

Though we have described the lava plain as level, it is not really so, but has a considerable slope south from Wallan, 1000ft. above the sea, and Gisborne 1500ft., till it passes out below sea-level at Williamstown and Point Cook, and over this sloping surface the rivers began to form their new channels. Pure

water can run for ages over comparatively soft rocks without cutting into them to any great extent; the cutting is done by the grains of sand, pebbles, and larger rock fragments which it carries along. The greater the slope the larger the material it can sweep along, and consequently its corrading power increases directly with the rapidity of the flow.

At first there would be no defined water-courses on the lava-plain; but gradually these would be scooped out in the hard rock. Once the streams got through this crust they found softer rocks below, and then they began to deepen their beds rapidly. The lava cap protects the sides of these valleys, and they are consequently steep.

When the streams pass through country where lava is absent the side slopes are more gentle. This may be seen in many places. For instance, just north of Coburg, the Merri Creek cuts its way through a lava plain, and lies in a steep-sided valley. Then at the back of Pentridge it runs along the boundary between the bluestone on the west and the red sands of Preston on the east. Its west bank is precipitous, but to the east a gentle slope sweeps up through the Coburg Cemetery to the sandy plateau above. Further down stream the valley is again bounded by bluestone on both banks, and the gorge spanned by the Northcote bridge is the result.

The general aspect then of a lava flow like that of our bluestone plains is an almost level expanse, scarred by deep gorges, at the bottom of which flow the creeks to which they owe their origin. These characters are to be seen over thousands of square

6.—Barwon at Pollock's Ford, west of Geelong. A typical gorge cut through the bluestone plain.

miles in Victoria, and can be well studied about Melbourne itself.

The great western bluestone plain is bounded on the east by the mouth of the Yarra, where it forms the point on which Williamstown is built. To the northward it skirts the Saltwater River, which it crosses above Maribyrnong. Thence it spreads to the north of Essendon, over to Coburg, and as far as the Darebin Creek. A long tongue passes south along the Merri Creek, and down through Fitzroy and Collingwood, past Burnley and Richmond, till we lose it at Queen's-bridge. Its level character has offered sites for most of our cricket-grounds—Fitzroy, Collingwood, Richmond, Melbourne, and East Melbourne.

Reference has been made to the chemical composition of bluestone. Its dark colour and heavy character are due to the large amount of iron it contains, and besides this it consists mainly of a compound of silica, or quartz, and aluminium, with a fair amount of soda and lime. In addition, like most rocks which have cooled from a molten state, it contains many other substances which we need not refer to.

If a flake of the rock be ground down till it is thin enough to be almost transparent, the microscope shows it to consist in the main of closely-matted, needle-like crystals, and to this structure is due the toughness of the rock. It is not as hard as quartz, but quartz is brittle. Granite, again, is on the whole harder, but its constituents are more varied and differently arranged, so that it more readily breaks up to dust under repeated blows. It is to the toughness

of bluestone that is due its suitability for road metal and pavement, in which it far excels quartz and granite, and this makes our bluestone plain of such great economic importance.

Like all other rocks, bluestone is acted on by the weather. Its component crystals are decomposed; the soluble parts are dissolved out and washed away, and when the process is complete a soft white clay alone remains. A clay produced in this way from the decomposition of a bluestone of greater age than that forming the lava plain may be seen in the railway cutting in Royal Park, near the Flemington-bridge station, and will be referred to in a subsequent chapter.

The surface of the whole of the lava plain has been weathered to a certain extent, and the products, mixed with decomposed plant remains, give us the stiff black or chocolate soil so characteristic of bluestone country. But the layer of soil is thin, and below it is the great sheet of dense, almost impervious rock. The rain-water runs off instead of sinking in, and when summer comes the supply is exhausted at once. The impervious nature of the rock below does not allow a fresh supply to be brought up by capillary attraction from beneath, and plant life suffers. To this cause, chiefly, is due the absence of trees and shrubs on all such plains; another cause being, of course, the fact that trees cannot force their roots down through the hard, unaltered rock. The soil, bulk for bulk, is far richer in plant food than the sands of the eastern suburbs, but these hold water like a sponge, and as fast as the surface dries, fresh

supplies are soaked up from below. So we have the peculiarity of a far greater amount and variety of plant life being found on the poorer soil than is present on the richer one. Plants need water not only for its own sake, but because it contains dissolved in it the foods that they require. The whole thing is a question of texture of the soil. In some parts of Victoria the volcanoes have blown a great deal of the bluestone to dust and cinder-like fragments, and the rock is readily permeable by water, with the result that trees grow freely, as, for instance, about the flanks of Mount Leura at Camperdown, and Buninyong, near Ballarat.

Allusion was made to the fact that the old land surface now levelled off by the bluestone was of an uneven character. Like the country to the eastward, it was diversified by hill and valley, and where we can see what is under the lava we find that the same red sands and gravels occur. The same soil, under the same climate, would bear the same vegetation, so that could we have seen the country about Footscray and Keilor before the upwelling of the bluestone, we should have found, not a wide treeless expanse of level land, rich in nutritious grass, but rolling hill and dale, clothed with a wealth of bright flowering shrubs and fine old gums, a generous home for insect and for bird.

CHAPTER IV.

The Yarra Delta.

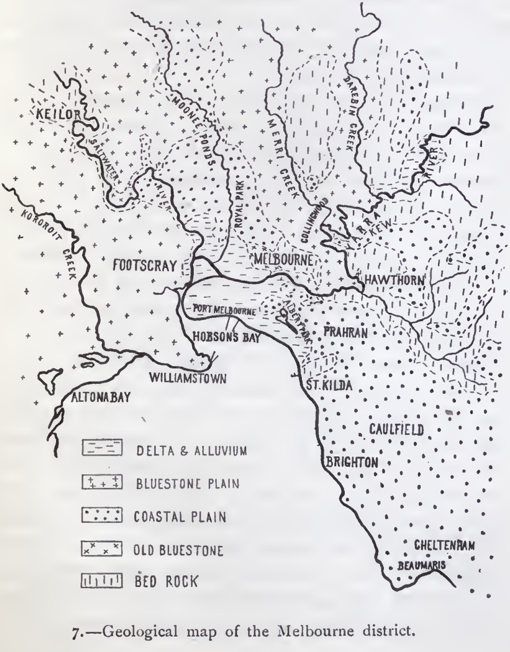
In our earlier chapters we dealt with the red-sand plain of the eastern side of Melbourne, and the bluestone plain of the western. We saw that the diversified scenery of Toorak, Kew, and Box Hill is due to the action of streams cutting through loosely-compacted beds, or as it is stated in the technical language of the geographer, the plain has been dissected. The bluestone plain of the west has also been dissected, but the process has not been carried nearly so far, for the operation began at a much later date, and moreover the bluestone cap is more resistant than the sands.

Besides these two types of plain, there is another —smaller and younger—but still of sufficient importance to merit separate treatment. This is the plain that forms the Yarra delta.

The typical delta, from which all others take their name, is, of course, the triangular one of the Nile, and from its shape the name delta has come to be applied to the deposits of sand, gravel, and mud which rivers lay down at their mouths. The mode of formation and the position at a river mouth are the essential points. The shape, which may be due to a variety of causes, is of no importance.

Standing on the high ground, above the North Melbourne railway station, we see, spread out before us, that flat expanse, part of which we know as the West Melbourne Swamp. It is bounded on the west

by a low line of cliffs, sweeping from North Williamstown to Footscray, and it passes up the valley of the Saltwater, where its upper limit forms the "flat" of the Flemington racecourse. The grandstand and "The Hill" are on the sea-cliff, and the racecourse itself occupies the site of a former quiet bay. Passing eastwards, we can still trace the



7.—Geological map of the Melbourne district.

old cliffs past Kensington and North Melbourne. The railway offices at Spencer-street are on the slope of the cliff itself. We can detect the sharp rise in King-street and Queen-street, and then comes the interruption of the old gully, or intermittent creek, up the gradual slope of whose valley Elizabeth-street runs.

For our present purposes we may put the inner end of the delta at Prince's Bridge. St. Kilda-road and Fitzroy-street, St. Kilda, may be taken roughly as its boundary on the east.

Standing out from the other high ground is the old island of South Melbourne, or rather, that part of it formerly known as Emerald Hill. All the flat ground circumscribed by the higher land was once an arm of the bay, which has been filled by the material brought down by the now conjoined streams of the Yarra and Saltwater. How thick the deposit may be is not definitely settled, but a boring put down in 1904 near the Port Melbourne railway line did not find bed-rock at 170ft.

From this we learn two things—firstly, that the amount of recently-transported material is enormous; and, secondly, that a very large and deep valley was formerly cut out by streams. Rivers and streams cannot erode very much below the level of the sea, into which they discharge. Their currents are checked, and the lighter fresh water tends to over-ride the denser salt water, so that material is deposited rather than removed. From the presence of this old and now hidden valley, then, we may conclude that the land once stood higher in relation to

the sea than it does now, that subsidence took place, and in the drowned valley the delta deposits were laid down.

The amount of solid material brought down by the rivers to form this great deposit may, at first sight, appear to make too great demands on our powers of belief. But it must be remembered that we have seen clear evidence of the removal of a vast amount of material during the dissection of the red sandy plateau and the bluestone plain. In the one case, there is evidence of denudation, in the other of accumulation, but we cannot accurately measure the amount of either.

The cutting of the Coode Canal, some years ago, and the work of deepening and widening the river gave us an opportunity of examining the material of which the delta consists, at any rate in its upper layers. This was seen to be in the main a fine, black mud or silt, and in places it was crowded with shells, the fossil remains of sea-dwellers in this wider extension of Hobson's Bay. Besides shellfish, there have been found the skull of a porpoise, the remains of schnapper, and barnacles in plenty. These fossils show us that the material forming the great deposit was laid down in salt water, and as the animals died, their remains were buried in the mud of the seaward marching land.

While the delta was yet young, the Yarra and the Saltwater entered the sea separately, the one near Prince's Bridge, and the other at the Flemington racecourse. The steady south-westerly winds banked up the mud and sand and turned the Yarra east-

wards, and it flowed between Emerald Hill and the Victoria Barracks. Gradually it filled in the bay between South Melbourne and St. Kilda. Sand bars blocked its mouth, and it found an easier path to the westward, where joining the Saltwater, it entered the sea under the lee of the bluestone ridge of Williamstown.

Once the river course became established in this sheltered position, a new state of affairs began. The south-westerly winds cause a great eddy in Hobson's Bay, so that the sand washed from the red cliffs to the south-east along the Brighton coast travels up towards Port Melbourne. This can be seen at the groins, or wooden bulwarks, running out from the shore about Middle Park. There is nearly always a bank formed along the eastern side of these erections, where the shifting sand is caught and held, and the beach is thus widened.

The sea-front of the delta deposit is, then, covered by a sheet of sand which is not river-borne, but is fresh material derived from quite a distinct source. If the supply of sand were more abundant, and the shore more exposed, we should have a series of high sand-dunes extending from St. Kilda to Spottiswoode, as it is, we have only dunes in miniature; from St. Kilda to Port Melbourne these have been improved out of existence, but a few years ago the surface here near the sea was a rolling sandy waste. To the west of the Port Melbourne railway line we can still see the undulating ground caused by the landward march of the dunes over the level silt-plain. It is on this sandy waste that the rifle range

is situated. The sand is of considerable value to builders though all the newspaper reader hears of it is in reference to sand-stealers who have dispensed with the necessary license, and it is this belt of sand again that gave the former name of Sandridge to Port Melbourne.

Just as the red sands of the Brighton district, and the bluestone plains to the westward have their distinct series of plants and animals, so has the delta-plain. Much of its original character has been modified by man. Square miles of swamp have been reclaimed by river silt piled on it by the dredges, and here, of course, the original vegetation has disappeared. The West Melbourne Swamp exists almost only in name, and no longer swarms with wild fowl. The dense tea-tree scrub that lined the lower reaches of the Yarra and the Saltwater has completely disappeared. Such a supply of firewood in this no-man's land could not be resisted, though a quarter of a century ago, it was still thick about the junction of the two rivers. A few shapely honeysuckles formerly grew along the margin of the bay, but now half-a-dozen scraggy tea-trees are all that remain of the little woodland. Where the sand has not encroached we find samphire scrub and pink flowering pig's-face, both plants that can endure salt water and a heavy soil.

The struggle between plant life and drifting sand can be studied near the river mouth. The first grasses to appear are those, with long, creeping stems, which put out roots from their joints. There are many kinds of these, and they bind the sand so that other

plants can then find a footing. Man has stepped in to the fray, and a large area along the road to the steam ferry leading to North Williamstown is planted with Marram grass, the finest of all sand-stays. Along the shore the coast-loving tamarisk, with its bright pink flowers, has been extensively planted, while everywhere imported weeds are widely spread.

About Albert Park the sandy coast is now built on, and its inhabitants make a gallant effort to grow gardens in the sand. The old swamp, instead of being filled, has been deepened to form a lake, and here a few wild fowl still find a home.

Glancing then at the results we have obtained, we see that Melbourne and its suburbs are built on plains of three distinct types. The red-sand plain, which has been deeply cut into by streams, and carved into hill and valley is occupied by the suburbs east of the Yarra; the plateaux of Carlton and Essendon are parts of the same great sheet of sands and gravels; Alphington, Collingwood and Richmond, and further west, Coburg and Footscray lie on the bluestone plain; while Albert Park and Port Melbourne are built on the great Yarra delta. Each of these three types of plain by its scenery, and by its plants, tells us something of its past history, and of the character of the rocks that lie beneath the surface soil.

CHAPTER V.

The River Flats of Heidelberg and Gardiner's Creek.

If we stand on the bridge over the Yarra at Heidelberg our attention is attracted by the wide flat through which the river runs. Across this flat it winds in wide-swinging, apparently aimless curves, as though the last thing that occurred to it was whether it would ever reach the sea. A walk over the level ground soon brings us to the edge of some long, serpentine channel, bordered with wattle and gum, or perhaps with a thick belt of tea-tree along its margin. At first, we probably take it for one of the river loops, till on following it for some distance we find that it comes to an end, and dies away in a narrow, winding swamp, overgrown with bulrushes and reeds. A little further and these have disappeared, and firm ground, clothed with thickly-strewn clumps of tussock-grass takes its place. In the language of the country it is a blind-creek or a billabong.

A little later on we strike the river itself, flowing slowly between two long ridges of firm ground covered with trees and shrubs. On one side of the ridge we are on is the river, and on the other lies a swamp. Then we come to a place where the river seems to divide as we follow it down stream. In the branch we trace the water seems stagnant. The channel bends once or twice, and then ends in a

narrow marsh. Beyond this the winding depression is dry for some distance, and then we come on a long curving waterhole lying in the channel. Following this low-lying strip of ground as it winds now here and now there, at times approaching the river and again swinging far from it, we at last find it once more joining the main river channel.

8.—Yarra valley above Kew. In the foreground is a billabong with rushes. The trees at the foot of the hill in the background mark the river course.

Then one fact about the billabong grows clear. It is a deserted river-course, and was once the bed of the stream. In places we can see where the river, by cutting through a narrow neck and keeping straight on in its course, might shorten its length

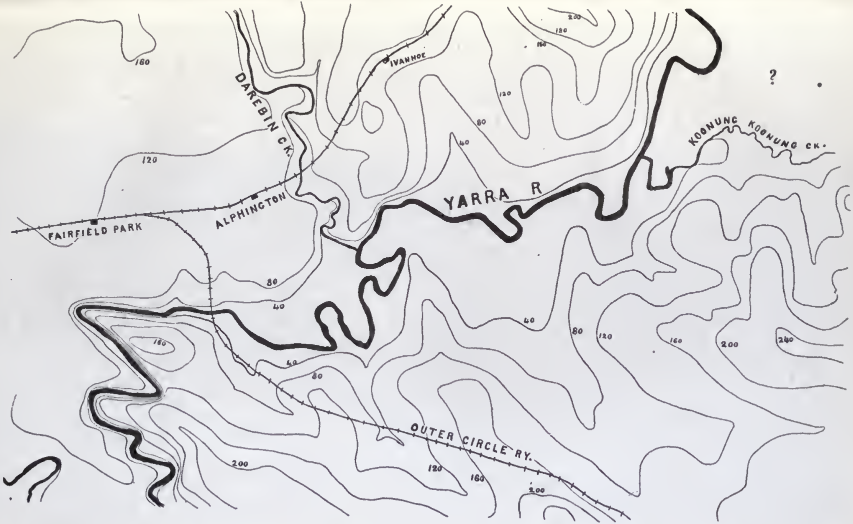
9.—Billabong in the Yarra valley at Bulleen.

and leave a winding curve deserted to form a new billabong. But the formation of all billabongs is not as simple as this, for very often the new river-course is longer and more tedious than the old; the stream has not shortened its path to the sea, but lengthened it.

We noticed that along the edge of the river, we had a bank of high, firm ground which held in the stream like a wall. Such walls are called levees, and are built up by the stream. The current is fastest in mid-stream in straight reaches, and twigs and leaves and other rubbish drift towards the banks and gradually come to rest. Amongst them the river silt accumulates, and reeds and rushes find a resting place. If a slight freshet occurs more rubbish is piled up, and gradually the ground becomes firm enough for bushes and trees to grow. The slight floods add more and more material to the levee and it increases in height and breadth.

Meanwhile during the periods when the stream is low, it is steadily filling up the hollows in its bed with sand and silt, and gradually raising the whole of it to a higher level. So that the tendency of the stream, when flowing over wide flats like this, is to lift its bed till it forms what we may describe as a deep groove running along the top of a long winding ridge. No silt has been piled on the flats on either side, and they are covered with swamps that may be lower than the river itself.

Then comes a flood. The narrow channel cannot carry all the water, and here and there the levees break down, and the flood-waters spread over the



10.—Contoured map of the Yarra valley near Alphington. If the land sank, say, 80 feet, and the sea flowed inland, the line marked 80 would form the shore line. Where the lines are far apart the slope is gradual, where they are crowded it is steep.

plain. The silt in the river-bed is torn up, and piled in great heaps which, near a gap in the levee, may partly block the channel, especially if aided by floating wreckage and stranded trees. A new channel is scoured out, and when the flood subsides the river is found to flow in a different course, and then once more it begins to form levees and raise its bed.

Again and again is the process repeated till we find the flat covered with a maze of ridges and winding swamps.

To all this the reader may possibly object that the work that rivers do is to carve out valleys, and to carry away the material to the sea, and yet here a river is described as raising its bed instead of lowering it, and as piling up sediment rather than removing it. He may ask, Why is it that down-stream about Studley Park no deposit of material is taking place, but the river is steadily sawing its gorge deeper and deeper, while accumulation is going on over the Heidelberg flats.

If we take the train to Fairfield and walk along the disused railway line to the bridge over the Yarra, we see that we are on a bluestone plain. The bluestone flowed down the old valleys of the Darebin and Merri Creeks as a deep, wide flood, and the united stream passed down the Yarra Valley, where its level surface forms the Collingwood and Richmond flats. Then, passing through Burnley, it ran on as a lessening stream till it came to a standstill somewhere about Queen's Bridge. It buried the old river courses deep beneath a cover of hard, dense rock. The former main valley ran near the great

11.—The Yarra gorge, seen from the Fairfield railway bridge. The lava flow on the right hand dammed the river, and so brought about the formation of the Heidelberg flats.

bluestone quarries of Collingwood, then crossed what is now Victoria-street between Church and Hoddle-streets. About the Burnley station it turned west and then kept near the course of the present Yarra.

One effect of this great lava flood was to check the flow of the river above the Fairfield railway bridge. The river had to flow at a higher level across the obstruction and then began to rasp away a new channel, partly through the bluestone, but mainly through the bed-rock. As it cut away the foot of the gentle slopes of the old hills, it replaced them by the cliffs that now bound the Yarra on its eastern side about Kew and Toorak

Meanwhile, above Fairfield, changes of quite another character had taken place. The old valley was perhaps turned into a long, winding lake that reached nearly to Templestowe, and even passed a little way up the valley of the Plenty. However, whether an actual lake was formed or not, there was a checking of the current, and the old valley began to fill with sediment. Deeper and deeper grew the accumulations and wider and wider they spread, lifting the river bed continually above its old level till now it lies, perhaps, if we may guess, some fifty feet above the bed-rock bottom. Each addition meant a further checking of the river up stream, so the plain grew backwards up the valley to Templestowe and up the Plenty Valley, where a mile above its junction with the Yarra the alluvium is thirty feet deep.

Above Templestowe the river bed is rocky, and the valley is V-shaped in cross-section. If we stand

12.—The Yarra valley above Alphington. Notice the wide valley as compared with that shown in fig. 11.

on one of the hill-slopes, and, in our imagination, cover it deeply with river-sand and silt till we have broad river-flats with billabongs and river levees, then we are in a condition to picture what actually lies beneath the river flats of Heidelberg, and picture it probably with a close approach to truth.

The Gardiner's Creek Flats.

Nearer to Melbourne we can see another case which compares well with the Heidelberg one. The same bluestone flow has dammed back the valley of Gardiner's Creek, and an alluvial plain runs up the stream for several miles.

This plain is now being cut into by the creek, and it is interesting to enquire why this is?

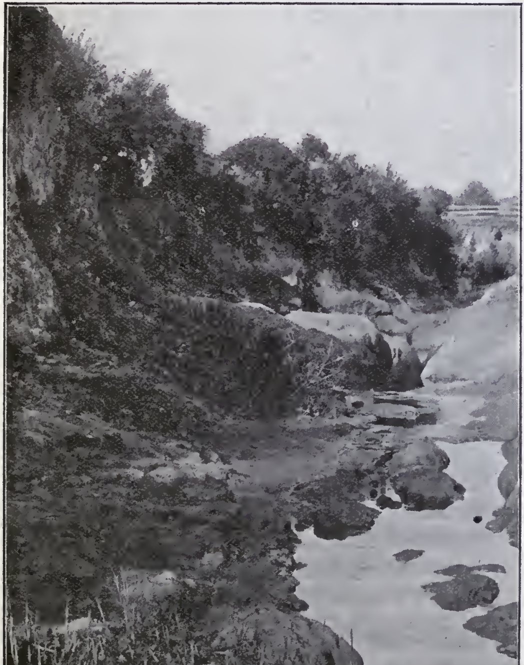
Generally speaking the rapid deepening of a stream-bed is due to one of two causes. Either an obstructing dam has been cut through, or there has been an elevation of the land, the result in both cases being that removal of material is made possible.

Here, however, the case is, in a sense, different. The deepening has begun but recently, for the tiny canyon, not more than twenty feet deep anywhere, is quite narrow, and yet it is growing so rapidly that bridges over it have constantly to be renewed, for their abutments quickly wash away. Some of these bridges about Gardiner, built in the days of the "land boom," are now impassable from this cause.

The deepening cannot have begun more than twenty or thirty years ago, and the tributary streams are all rapidly cutting back through the sandy beds. An examination of some of the other creeks to the

east of Melbourne will throw some light on the problem.

The Koonung-Koonung Creek flows along the southern slope of Doncaster Hill, and enters the



13.—Banks of Gardiner's Creek. The alluvium is being cut into very rapidly, so that a small canyon is formed.

Yarra about two miles south of Heidelberg. Where it is in its natural state, it is mantled by a thick growth of tea-tree. At times of heavy rain, when the little stream overflows its bed, it spreads over the scrub-covered flat. Through the thick undergrowth it can flow but slowly, and the soil, firmly bound by the tangled mass of roots, strongly resists any attempt to work it into holes.

The surrounding country, too, is but little altered by the hand of man, and the timber-covered slopes check the water on the hills, and it takes days and weeks to reach the bed of the valley below.

In the lower part of Gardiner's Creek all this is different. The thick tea-tree scrub has been cut down, though not so very long ago it was dense even down to Burnley. The water from Surrey Hills, Canterbury and East Camberwell is hurried into the creek through paved drains, and every swamp has a trench cut from it. The result is that a heavy shower swells the creek to a raging flood, and as the protecting scrub with its binding roots is gone there is nothing to prevent the loose alluvium from disappearing at a marvellous rate.

There is a moral to this story of Gardiner's Creek which has a wide application and which needs but to be pointed out. The cutting down of forests over large areas increases the danger of floods by pouring into the river water that should have taken weeks or months to find a way into them. In such regions then, as we learn from all over the world, the tendency of rivers is to disappear in dry weather and to become raging torrents in seasons of rain.

CHAPTER VI.

THE TERRACES OF MOONEE VALLEY.

The valley of the Moonee Ponds Creek is broad and flat-bottomed, and the bounding hills, for the most part, slope gently down to the wide sandy flats. The material forming these stretches of alluvium is derived from the rocks of the surrounding country, and it is not till we approach Essendon, where the red sandy beds of the coastal plain begin to be covered by the bluestone of the plains, that the sands give place to dark rich soil derived from the wasting of the lava. Here the alluvial soil is largely cultivated, but further down stream it is not so suitable for this purpose, though its level character has furnished a site for the Moonee Valley racecourse.

If we walk up the valley from Flemington Bridge we can see that the plain has been cut into by the stream, so that there are two flats, one about twenty feet above the other. The upper flat, being raised above the other, is spoken of as a terrace. The lower flat is cut into only for two or three feet by the stream, which in flood time covers it. So it is known as a flood plain, and as the little flood-plain is practically on the level of the Yarra delta, it may be regarded as its upper end. But the upper flat, or terrace, is itself river-built, and is formed of sandy alluvium. It is an old flood-plain.

Here then we have an example of an old flood-plain being cut into by the stream which, instead of piling up material over the lower part of its course, is actually engaged in removing it. In dealing with

the alluvial flats of Gardiner's Creek the two causes which generally bring about such a change in the behaviour of a stream were drawn attention to. They were, it will be remembered, the removal of a barrier, or the elevation of the land. There is no barrier the removal of which would be effective in this case, and we feel compelled to ascribe the change to elevation.

14.—Moonee Valley. The creek flows past the foot of the terrace, across the whole width of the picture. The cattle are grazing on the flood plain.

In the case of Gardiner's Creek, the excavation of the alluvium was seen to be due to an exceptional cause—namely, the destruction of the protecting trees and scrub. There was evidence that the change began only a few years ago. At Flemington Bridge the change is geologically recent, but that may mean

anything up to many hundreds of years. It is quite certain that as far as years go the little flood plain is of great antiquity, so that scrub cutting will not satisfy the case in this instance.

If we look about for other evidence of a comparatively recent, slight uplift of the land which would be effective in bringing about the change in the behaviour of the stream we have not far to seek.

Let us consider what would be the result of an uplift of say twenty feet about Port Phillip. There are many mud flats round the shores which are alive with shell-fish, and at low tide they can be dug up in great numbers. The suggested elevation would turn these tidal flats into broad belts of dry land, and then on the land above sea level we should be able to dig up any quantity of the shells of those animals that lived in the mud when it lay below the sea. Below the tidal level the character of the shells differs somewhat from those found between tide-marks, for there are some animals which are quickly killed by even an hour or two's exposure to the air. Besides this, the shells below tidal limits are not, as a whole, so corroded as those above, at least in the case of many species. In other words, some shell-fish, even if they come up into quite shallow water, are more healthy and vigorous at greater depths. We are able then by examining the shells that might occur on such a raised portion of the sea bed to form a very shrewd guess as to whether the elevation is only a foot or two, or whether it was a great many feet. We cannot be very exact about this, but we can form a rough idea.

Then, as regards the time at which the elevation took place. If all the shells in the deposit are such as now live in the water close at hand, and if all the species occur in the same proportion in the raised beds as they do in the present sea bottom, then we are justified in saying that the elevation is quite recent, it may have been only last year perhaps. But supposing we find that, though all the species are still living, the relative abundance of a species in the neighbourhood is different, then we are safe in putting the elevation further back in time. It is still very recent, but there has been time for conditions to alter, and for the alteration to affect the conservative and slowly changing dwellers in the sea.

The application of all this lies in the fact that round the head of Altona Bay, as far north-easterly as the Williamstown racecourse, and inland up the shallow valley of Skeleton Creek for some distance beyond the Geelong railway line, there is an extensive sheet of shell-bearing silt. The silt lies on top of the bluestone of the plain, therefore it is younger than the lava. It is several feet thick, so its deposition was not effected in a day or two, nor a year or two. Generation after generation of shell-fish of various kinds, were born, grew to old age and died. So that the elevation did not take place for perhaps hundreds of years after the boiling flood of lava had solidified and cooled down.

The shells of this deposit have been carefully examined. They all live in the bay to-day, but there seems to be a difference in the proportion in which some species are found, so that we may conclude that

the elevation was not a thing of yesterday. Then again, if the elevation had taken place in quite recent times, that is in years, we should expect to find such raised beaches far more common than they are. They are not uncommon, but they are decidedly not almost universal, in other words the waves, working inland, have destroyed most of them.

The beds do not go very far inland, that is do not rise very far above the present sea level. Probably twenty feet of elevation is the outside limit we can claim.

We can now bring two apparently unrelated facts into relationship. At first sight there would seem to be no connection between the occurrence of shells a mile or so inland from the shore, at Laverton, and the presence of terraces in the lower part of the Moonee Ponds Valley. But both facts demand an elevation of the land for their causation. The elevation must have been geologically recent in each case, and yet it must have occurred, in what from a human standpoint, we must speak of as ages ago. Finally the amount of elevation must have been somewhere in the neighbourhood of twenty feet.

CHAPTER VII.

THE BED-ROCK OF MELBOURNE.

There is an old Hindu fable that says the world is supported by an elephant and the elephant stands on a tortoise. A subsequent commentator tells us

there is nothing under the tortoise, because its legs reach all the way down. Like the Hindu we must needs ask what underlies the young and superficial rocks which cover such a large area of the country about Melbourne, the red sands of the east, the bluestone of the west, and the silt of the Yarra delta.

There are two ways in which such a question may be answered. We may dig or bore through the younger rocks, or we may look for places where the denuding action of streams has cut through them, and laid bare the platform on which they rest. Fortunately, the latter method is available for us, and in many places we can see the bed-rock exposed. Popular language in Victoria applies the term "schist" to such rock, but, like so many popular terms, it is incorrect, for schist has a definite meaning. Unfortunately there is no scientific name which will describe the rocks simply. They vary so much in their composition and structure that a single term is inapplicable. We may then fall back on the noncommittal term of "bed-rock."

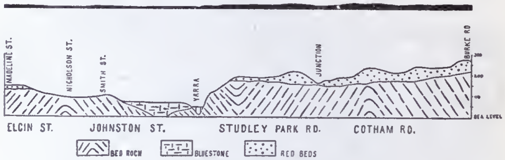
The bed-rock may be examined at many places of easy access, at Dight's Falls, in the road cuttings near the Johnston and Victoria streets bridges, at the Chapel-street bridge in Prahran, in railway cuttings at South Yarra (between the signal-box and the river), Hawthorn, Barker's-road and Royal Park; along the Yarra by Alexandra-avenue, in the Moonee Ponds Creek near the racecourse, along the Saltwater above Maribyrnong, and in the brick pits of Brunswick and Auburn. In all these places, and in many another, the rocks are seen to consist of

layers seldom more than a foot in thickness. These layers are composed of hard sandstones of fairly fine grain, and of clay rocks which have also been hardened, and which usually break up easily into somewhat cubical fragments. Near the surface they are generally fawn-coloured or brown, from the presence

15.—Auburn Brick-Pits, showing the tilted bed-rock. The layers were originally horizontal.

of iron rust or iron oxide. In deep excavations, like the enormous one in the Hoffman Company's brick pit at Albion-street, Brunswick, they are grey or bluish, because the percolating water from the surface has not been able to rust all the iron they contain.

Rocks composed of such even layers of sand and mud as these are must have been laid down under water. But there is a remarkable peculiarity about them, in that the layers are not horizontal, but stand up on edge, like books on a library shelf. In some places, as in front of the Police Court in Latrobe-street, they are crumpled, while in the cutting at the Victoria-street bridge,



16.—Section from the University gates, in Madeline-street, to the corner of Cotham and Burke roads, Kew. The red sands of the coastal plain are cut through by the old Yarra valley. A bluestone flow has partly filled this valley, and the river has been forced to carve a new channel. The black line above the section shows the true form of the surface, the lower section being exaggerated for clearness.

they are seen to be bent up in the form of an arch. The cause of this folding and crumpling of the rock-layers is not fully understood, but the generally accepted explanation is that the cooling earth shrinks, and as it shrinks the already cooled and consolidated rocks that form the crust must buckle and wrinkle, as they seek to fit themselves on to the decreasing central mass. The older the rocks are the more time have they had to suffer this folding; and, consequently, old rocks almost always

show evidence of great strain. They are folded and broken, and compressed till they form hard masses. In Victoria, generally, we may say that tilted and folded rocks are old, while horizontal, undisturbed rocks are young. The rule is, however, not of universal application, for in the Baltic provinces of Russia, for instance, rocks as old as our bed-rock consist of soft horizontal clays, so that a stranger would mistake them for quite young strata ; while in the European Alps beds as young as our red sands are more tilted and compressed than our bed-rock itself.

Hitherto we have abstained from using the terms by which geologists indicate the age of the rock with which they deal ; used without any explanation the names are meaningless terms ; they sound learned, but leave us in a fog. Geologists long ago recognised that they had no data for even a wild guess as to the age of rocks in years, and the periods dealt with are so vast that, even if it were possible to measure them, we could not grasp the meaning of the figures. We are forced then to adopt another plan and merely to speak of the relative ages of the rocks. It was recognised that as we passed from younger rocks to older there was a change in the character of the contained fossils. The youngest rocks, like those of the Yarra delta for instance, yield fossils which are all exactly like animals living along our coasts to-day. Many of the fossils of the red sands are extinct, while those of the bed-rock of Melbourne are all extinct, and several of the great groups of the animal kingdom they represent have

long since passed out of existence. No fish like those now living then lived. Amphibia, reptiles, birds and mammals had not yet been evolved. There were probably no grasses, while flowering plants as yet had not appeared. Broadly speaking, we can find rocks in other parts of the world of the same age as our delta deposits, the red sands and the bed-rock, and we need terms to express this agreement in age. It is of interest to find that lawyers are on our side in this matter. They are accustomed to speak of Acts of Parliament, not by the year in which they were passed, but by the year of the Sovereign's reign in which this took place. They quote them, using their own shorthand methods, of course, as Acts of, for example the 7th year of Elizabeth, or 10th of Charles I., and so on. It is necessary, then, for them to learn the list of English Sovereigns, in their proper order, for if two Acts conflict, the more recent holds. They learn this list while they are as yet innocent, though a high authority tells me that they generally forget them later.

In a similar way the geologist learns off the names of a string of "periods," as he calls them, and is content to refer rocks to these periods, or to some named subdivision of them. The actual date is of no importance, for he never can find it out.

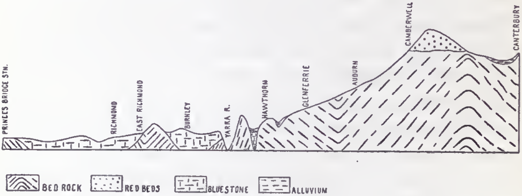
For instance, a set of beds and its contained fossils was worked out in a district in Wales once inhabited by a tribe called the Silures. The rocks were conveniently called Silurian. Then other beds with a fairly similar set of fossils received the same name; and, later on, rocks of Silurian age were recognised

all over the world, including our Melbourne bed-rock, and we call them all Silurian. The composition and structure of these rocks have nothing to do with their name; by Silurian, we mean merely that they are of a certain relative age. They are younger, for instance, than Cambrian, older than Devonian, just as an Act of Parliament of Anne's reign would be younger than one of Elizabeth's, and older than one of Victoria's.

The fossils of the bed-rock are not, as a rule, well preserved, nor are they plentiful. They may be found at the foot of the cliff on the Moonee Ponds Creek, just above the Brunswick-road bridge, and near the Johnston-street bridge. A large number were procured while the Yarra improvement works were in progress near the Botanical Gardens. Further afield, the Lilydale limestone quarries have yielded some very fine specimens, and if permission to visit the quarries be obtained, a good bagful may always be gathered. There are many places in the same neighbourhood that will repay a visit, but one needs a guide. Near Keilor, at the bend below the bridge, graptolites may be obtained. They are an extinct group, with no popularly known relatives now living. Before setting out to look for fossils, it would be as well for budding geologists to spend an hour or two examining in the Museum the fine collection of those of the Melbourne district, in order to get an idea what to look for.

Over a large area, where the bed-rock may be found near the surface, it is thinly mantled by a layer of sand, which has been washed over it from

the red sands at a higher level. The result is that, as the beds are highly inclined, they drain well, and the sandy soil which at first seems similar to that of the red sands, bears a different class of vegetation. Most of this has now disappeared about the suburbs, but in some places a few grand old redgums have escaped the axe of the spoiler, and short nutritious grass replaces the scrub usually found on the red sands.



17.—Section along the railway line from Prince's Bridge to Canterbury. The heights are exaggerated. Compare with the geological map of Melbourne.

Excepting for the river cliffs the bed-rock does not offer, about Melbourne, any important landscape features that can be readily grasped. Economically it is of considerable importance, for from the old clay-rocks are made all the red bricks and pottery which are used about Melbourne. The enormous excavations which have been made for these purposes must be seen to be understood. There are good ones at Brunswick, Northcote, Auburn and Mitcham, and they are worth an hour or so being spent in them.

Injected Rocks.

The old rocks have been rent and broken in many places by earth movements, and sheets of molten rock from far deeper levels have been forced into the cracks. Usually these sheets have now decomposed to clay, or to a mixture of clay and sand, according to the nature of the intrusive rock. There are several such dykes, as these intrusions are called, in the cutting at the Victoria-street bridge and in that in Chapel-street. There is another in the cliff at Alexandra-avenue, now, unfortunately, almost hidden by greenery. The greatest of all cannot be detected at the surface, but it runs up the valley that reaches the Yarra at Cremorne bridge. It is weathered to a sandy clay, and yields the material used in the brick pits near the South Yarra tram sheds and at Malvern. The rough pottery made from it is white, as there is very little iron in the clay. It resembles a decomposed granite, and a quartz sand, such as would be derived from a similar rock, consisting of large irregular grains, is found both in the "Red-beds" and in the delta beds as well. The source of this granitic sand was a puzzle till the sewerage works showed the presence of these great dykes.

As, then, the bed-rock is seamed with these great sheets of granite-like rock, we may assume that the Hindu tortoise is represented by a rock having a somewhat similar composition and structure to the dykes, and, like the Hindu, we need at present seek no further.

CHAPTER VIII.

More Melbourne Rocks.

Besides the rocks which form the plains and the bed-rock, with its intrusive masses, there are others which may be mentioned. The bluestone of the plain to the west is not our only bluestone. There is an older series of lava-sheets, which are not younger than the "Red-beds," but older, for where both occur together, the "Red-beds" are on top. This may be seen in the railway cutting in Royal Park, near the Flemington-bridge station. It requires a good deal of care to recognise the bluestone here, for it has decomposed where it lies into a greasy, fawn-coloured clay that can be readily dug with a pocket-knife. It is about as unlike road metal as it can possibly be, and yet in the cutting we can trace the change from dense bluestone, that rings under the hammer, to soft clay. There are very few places within easy reach of Melbourne, where the weathering of hard rock, and its consequent complete change of character, can be so easily followed as in this cutting.

About a mile to the south-west of Keilor, a deep, steep-sided valley known as Green Gully enters the Saltwater River. The valley is floored with this older volcanic rock, which rises some distance up its sides, or, in other words, a deep gash has been cut into the bluestone by the little creek. Above this, on both sides of the valley, can be seen the red sands, containing fossils, which, however, are not very plentiful, as generations of geological students have col-

lected most that could be got without digging. In some places hereabouts the red sands are really red sands, but in others a few feet from them they are white, and have been cemented by quartz to a rock resembling porcelain. This effect has been caused by

18.—Railway cutting in Royal Park. The Red-beds of the coastal plain cover everything and come down to the level of the rails on the left. The light-coloured rock on the right is decomposed old bluestone. A small conical patch of bed-rock is seen at the rail-level (in the middle of the picture) under the bluestone.

water with silica in solution. Quartz is one form, but not the only form, of silica, so the two terms are not quite equivalent. What the source of this water was, or why it should have acted here, and not elsewhere, is not clear. One small patch of the beds here, which

we have for convenience called red sands, or "Red-beds," consists of limestone, made up almost entirely of fragments of fossils.

Above the "Red-beds" comes the bluestone of the Keilor plains. We have, then, in this gully three sets of rocks—an older volcanic rock at the bottom and a newer one at the top, while sandwiched in between are the "Red-beds," which are here of marine origin, as the fossils show.

The older volcanic rock, or older bluestone, may be seen in a good many places on the western side of Melbourne, as, for instance, in the Moonee Ponds Creek at Essendon. It forms a good deal of the hill on which North Melbourne is built, and is the rock which stands up like a wall beside the North Melbourne station, and can be seen in the cutting at the South Melbourne station. Generally it is decomposed to a rubbly rock, which can be dug with a pick. Tradition says that the contractors for the removal of Batman's Hill at the Spencer-street station sent in their tender under the impression that they would have to cut away hard bluestone, and that the results of the work were pecuniarily satisfactory to them.

The frowning cliffs of the coast from Cape Schanck to Flinders, and almost the whole of Phillip Island, consist of the same rock. We see, then, that there have been two distinct outpourings of bluestone in Southern Victoria. There may have been, and apparently were, more, but two are clearly distinguished about Melbourne—the one younger than the "Red-beds" and the other older.

Subdivision of the "Red-Beds."

Hitherto we have spoken of the "Red-beds" as though they were all of the same age, but this is not the case. It has been found that the fossils in those of the Brighton district, as a whole, are younger than those to the east. The fossils of the "Red-beds" are mainly in the form of impressions, such as a seal makes in wax. The lime of the fossil shells has been dissolved and carried away by percolating water, and only the spaces they filled remain. But we are as sure of the shape of the vanished fossil as we are of that of the seal when we examine the wax. In case of doubt we actually take a wax mould from the shell cast, and can then study it more easily. In other parts of the State the fossils are beautifully preserved, and have an extensive literature of their own. It is with these well-preserved examples that we compare the imperfect specimens of the "Red-beds."

A series of bores has been put down about Newport and Altona Bay which has thrown a good deal of light on the geology of the Melbourne district. The older "Red-beds" about Flemington are thin and sandy. They were laid down near the shore line, as is shown by their composition and by the fossils they contain. About Newport and Altona Bay they are much thicker; they no longer consist of red sands, but mainly a blue clay. The finer sediments point to a greater distance from the land, where only fine mud could be carried by the sea currents. The clay in places is full of beautiful shells, which can be extracted whole with ease. From the

bore-cores, and from the spoil heaps of two shafts, extensive collections of these fossils were made, though now the opportunity has passed.

Near the old cement works, a couple of miles south of Mornington, the same richly fossiliferous clays outcrop on the beach. A fine series of the fossils from these localities may be seen in the National Museum.

The Lignites.

On the east side of the Reformatory, in Royal Park, a gully runs down to join the Moonee Ponds Creek, and here, in a not very odoriferous locality, there occurs a deposit of white clay overlying the bed-rock. The white clay, near at hand, where the gully from the Zoological Gardens passes under the railway, can be seen to underlie the older volcanic rock. So it is of course older than this old lava, and older than the "Red-beds." Many years ago fossil leaves were found in these clays, which thus appear to represent a fresh-water deposit. The clays become thicker as we go towards Newport, and the plant remains become more abundant, forming beds of lignite or brown coal. At Newport this lignite was found under the blue marine clays, and was 12 feet thick. At Altona Bay it was much thicker, reaching as much as 70 feet. We are not sure what is immediately under the lignite in this place. Shells were reported, but, unfortunately, none were preserved for examination, and we are unable to tell the nature and age of the underlying deposit. At a greater depth the bed-rock was bored into.

As the lignites are a fresh-water deposit, accumulating in a swamp or lake, the sea did not cover the country there when it was being formed. In other words, the deposit must have been produced above sea-level. Subsequently the land sank below the sea, and the marine clays were laid down on the sinking surface till a great thickness of them was deposited on the top of the lignites. At this time the sea flooded the country as far north, at any rate, as Keilor, and perhaps further, though this has not been proved, for marine fossils have not been found in the "Red-beds" further inland than this locality.

It will be noted that the older volcanic rock was not mentioned as occurring about Altona Bay. None was found in the shafts and bores, so apparently the flow did not extend in that direction. It seems that there was a valley running through Kensington, North Melbourne, the Spencer-street station, and so on to the South Melbourne Hill. This was filled by the older lava. No trace of the high land bounding this valley on the southward now remains. We do not know what rock it consisted of, nor why it is missing. It may have been removed by denudation, or have been let down by faulting. There must have been high land hereabouts, for a lava stream, like water, will of course always seek the lowest ground, and where we see a lava ridge we must assume it to occupy what was once a valley. It is only a ridge, because the less resistant rocks on each side have been removed.

The two sets of rocks dealt with in this chapter, namely, the older volcanic and the leaf-beds, or lig-

nite series, are not marked features of the suburban area, but are extensively developed in other parts of the State. At Portarlington, for instance, the older volcanic forms the rich agricultural country for which that district is famous. The way in which the onion-growers have taken to soil formed from this rock, both there and in other parts of the State, is very remarkable.

The lignite series is well developed in parts of South Gippsland and near Dean's Marsh. There is a good deal in a name, especially for company flotation purposes, and our lignites are generally spoken of as brown coals. Hitherto they have not proved of much economic value to us, but doubtless their day will come, and the lignites of South Gippsland, Dean's Marsh and Altona Bay will prove valuable.

General Summary.

The oldest rock about Melbourne, the bed-rock, is of Silurian age. Its original horizontal sheets have been folded, crumpled and broken. It has been invaded by sheets of granitic rock and bluestone injected into it from below. These invading rocks are of course younger than the rocks they penetrate. Immensely younger than the bed-rock, but still very old, is the lignite series, laid down in fresh water. Then followed the outpouring of the older volcanic or the old bluestone series. Then came a partial submergence, and the red rocks forming the coastal plain were laid down. Their constituents were derived from the waste of older rocks of all sorts, as

their varied constitution shows. Granite, Silurian sandstones and shales and other rocks all contributed their quota. Still later followed the outpouring of the newer bluestone forming the western plain, and lastly we have the delta deposit, the fringe of small sand dunes about the Yarra mouth, and the alluvium of the valleys.

If we were to extend our survey a few miles beyond the suburban radius, we should add a few more formations to our list; but even as it stands we have a wealth of geological variety that no other large city in Australia can boast of. Only one town in Victoria approaches it in geological interest, and that is Geelong, which is a paradise for fossil collectors, and is the locality of many unsolved problems.

The differences of structure of these various rocks affect the underground drainage; some soak up a large amount of the rainfall, and store it in the spaces between their grains; others absorb but little water, and part with it slowly. The chemical composition of the rocks also varies. Some are rich in plant food, and others are poor. The effects of these differences are shown by the vegetation grown on the soil overlying the undecomposed rock. Where water circulates freely and roots can penetrate deeply, trees grow well: where impervious rock is but thinly mantled by soil, trees cannot grow, for two or three dry years will kill them off, as it does on the bluestone plains. The vegetation then is an index of the nature of the rocks below, and is constantly used by geologists in deciding on their character.

The plants afford food and shelter to animals

which thus vary with them. And lastly, the nature of the ground determines the direction in which the city spreads. The tendency of the residential suburbs is to keep to the undulating "Red-beds," leaving the monotonous bluestone plain for the business sites. A town does not grow at random, but its position is determined by a whole series of geographical and geological factors.

Part II.—Further Afield.

CHAPTER IX.

The Sand Dunes of Sorrento.

To the excursionist who passes in a steamer along the coast from Portsea to Sorrento the view, when seen for the first time, comes as a surprise. It looks like the scenery of the theatre. The dark blue sky, and bright green sea, the yellow cliffs hemming in tiny bays, and the white houses peeping from the dark, olive-green masses of tea-tree that cover the hills, are so very different from all we are familiar with elsewhere round Port Phillip that we cannot take our eyes from it, and are only sorry that it is all over so soon. The whole of the Sorrento Peninsula is a land of sand-dunes, some new and yet in the making, others past their prime and being removed by the very forces that moulded them. Some are still loose sand, while others are now in the form of hard, rugged rock, that makes the Back Beach so favourite a picnic-ground and forms so wild a coast.

The formation of sand-dunes by the wind is a process that can be studied on a small scale in the wind ripples that are formed everywhere on loose, dry sand. The line of the ripples is usually at right angles to the prevailing wind. There is a gradual ascent, a sharp crest, and then on the lee-side a steep

descent. The crest is always travelling to leeward, not in a perfectly straight line, but with a tendency to form crescent-like curves, with the convexity to windward. The little ridges unite with their neighbours and produce small, cup-like depressions, with no outlet.

All these features are reproduced on a large scale by the dunes themselves. The steady wind comes off the sea, and the crests of the dunes march inland, like successive waves. On climbing any of the heights along the Back Beach the country looks like a storm-tossed sea, but the waves are sand-hills, and are, for the most part, covered by a thick growth of scrub. In some places, however, the loose sand shows clearly, and here the inland march can be readily seen. In some places the green grass is still showing through a thin layer of the yellow sand; in others, the tips of the tea-tree alone can be seen, while close at hand rises up the sand-wave that will soon drown all.

A Shelly Sand.

The sea affords on this coast a never-failing supply of sand. Almost as fast as it blows away, more is supplied to take its place. And yet the peninsula is not covered by loose, bare sand, but, for the most part, by an almost impenetrable scrub, and where this is cleared a rich growth of short, sweet grass appears. To find the reason for this, one must examine the sand closely and see what it is composed of. Most of us require a lens to do this with, but the keen-eyed can see a good deal without its aid. The sand is not uniform in colour, but is speckled,

pepper-and-salt looking. There are very few, almost no clear crystal grains of quartz. A large number of the particles are milk-white, some are yellow, and a few are brown. Most of them are smooth and polished, from rubbing against one another as they drift along with the wind, and occasionally one can recognise small fragments of shells, while the expert can trace bits of many kinds of organisms besides. It is a sand, but not a quartz-sand.

We can apply a chemical test in a rough way. If some of the sand be placed in a saucer and acid be poured on, the mass begins to bubble and froth energetically. The most convenient acid to us is ordinary vinegar, though muriatic is better, and may be diluted with three or four times its bulk of water. If enough acid has been used we find, after the effervescence has ceased, that there is scarcely any residue, and what there is consists of clear quartz grains or black little specks of iron ore. From these results we may conclude that the bulk of the sand is formed of carbonate of lime, mainly in the form of shell chips. The whole peninsula, as far east as the high land stretching from Dromana to Cape Schanck, is, then, practically a mass of shell chips, so in its way it is almost as remarkable as a coral island, built up as it is of the remains of living things.

Dissolving of the Sands.

Carbonate of lime exists in many forms—marble, chalk (not school teachers' chalk, which is plaster of Paris), shells and several others. It is a substance that

is readily acted on by natural agents. Rain-water dissolves it by the help of the carbonic acid it contains, and to this cause is due the terribly rough surface of the bare rock along the Back Beach; it is corroded and dissolved away like a lump of sugar in water. The rain water, percolating through the sand-dunes, dissolves the edges of the shell fragments, and cements them together into a solid mass. The acids of decaying vegetation, which were dealt with in describing the red-sands at Beaumaris, act more powerfully in the same direction; and so it comes about that along the Back Beach we have hard rock, varying in density with the amount of action that has taken place. The hard, dense rock is merely the result of the cementing together of the loose sand, the cement being derived from the sand itself.

The action of rain-water on rock, then, varies very greatly with the nature of the rock. The red rocks of Beaumaris contain a great deal of quartz sand and a very little cement, which is mainly iron-rust. The action of rain-water on this is to remove all the iron, and leave loose, bleached sand. At Sorrento the same agent consolidates loose sand and forms hard rock.

Vegetation of the Dunes.

Once vegetation gets a hold on the Sorrento sand, then it continually makes the ground more suitable for plant life, for there is a fair amount of plant food and fresh water in the sand, and all that is needed is that drift should be checked. The fresh supplies of sand come from the ocean side of the peninsula, and

every foot of its march across the plant-covered surface becomes more and more difficult. It is not the single grain that injures the plant, but the overwhelming force of numbers. Consequently, except where the surface has been broken by man, moving

19.—Cliff at Barwon Heads, formed of dune-rock. The slanting lines on the right, near the top, show the old slope of the sand-dunes which formed the hill. (Photo. by Mr. A. Purnell.)

sand is not abundant on the bay side, while it is on the ocean side.

The rain that falls on such loose sandy country sinks in, and is easily reached by wells, which are common. In dry weather the water near the surface evaporates, and a further supply rises from below,

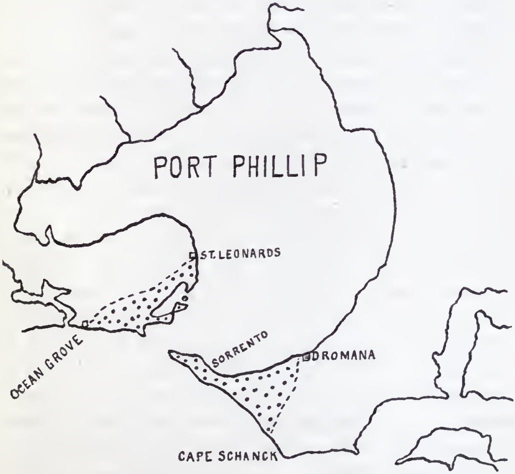
and is, in its turn, evaporated. This goes on constantly, and the lime, which has been dissolved, is carried to the surface, and there left when the water passes off. In course of time a sheet of rock produced in this way is formed, and it is this white rock that is burned for lime in the numerous kilns of the district.

Singular Incrustations.

There are some peculiar structures found in the dunes that attract most people's notice. Popularly they are known as fossil trees, which they very much resemble. They are white in colour, and generally furrowed on the outside. When they occur undisturbed they project from the loose sand like a thicket of shrubs.

If they are closely examined they are seen to be nearly all hollow, and to be composed of hard ringing limestone. In the hollow there is frequently to be found the remains of woody matter. This gave rise to the idea that they were real petrifactions, that is that the woody matter had been removed from the outside and replaced, particle by particle, by lime, the vegetable matter in the middle representing the portions that had not yet been acted upon. This idea is not, however, correct. It is the old story to which allusion has been made previously of the action of acids produced by the decay of vegetable matter. The shrubs and roots buried in the sand give off acids during their decay, and these acids have a strong solvent action on lime. The oxygen of the air causes the dissolved lime to be again precipitated,

and this takes place round the twig or branch, for no sooner does solution take place than precipitation occurs. The objects are then not petrifactions, but incrustations, and are found only in lime-sands like those of Sorrento.



20.—Map of Port Phillip. The dotted area shows the land formed by sand-dunes, which have thus nearly closed the mouth of the port.

A Nearly Closed Port.

Looking at the Sorrento peninsula as a whole, we see that it extends across the mouth of Port Phillip, like a great harbour bar. Beyond the opening of the Heads to the westward, we find another large area

formed by the same rock, including all that triangle lying between St. Leonard's, Ocean Grove and Point Lonsdale. Before this bar was formed by the waves and winds of Bass Strait, Port Phillip had a wide entrance, stretching from Ocean Grove to Cape Schanck. The sea could not quite bank it up, as the large area of the bay contains enough water for the tidal rush in and out to keep the entrance open.

The hard stone formed by the consolidation of the dunes is known as dune rock, and forms a striking feature of much of our coast. The lighthouses at Queenscliff and Point Lonsdale stand on it. It forms the high bluff at Barwon Heads. It shows as magnificent cliffs 200 feet high at the mouth of the Aire River, just beyond Cape Otway, and at Point Ronald at the mouth of the Gellibrand. Further west it protects the mouth of the Hopkins, and forms the picturesque Warrnambool cliffs. Warrnambool is built on a great sheet of it, and the rock itself is quarried and used for building there. It is easily worked, the builders cutting it with carpenters' saws when they are fitting a piece into a wall, but it is very porous, and, unless coated with stucco, allows the rain to soak through.

Fossils of the Dune Rock.

It is in this rock that the supposed human impressions found at Warrnambool occur. From the nature of its formation fossils are scarce, but the bones of a gigantic, extinct kangaroo were found a few years ago in it on the Back Beach at Sorrento, and a few shells have been found elsewhere.

The vegetation it supports is not very varied. The coast tea-tree grows well, as do the native currant, sheoak and honeysuckle. Sword grasses, bracken and rushes are common, and in some places the nutritious kangaroo grass affords good pasturage. The honeysuckles and currants, as well as other berry-yielding shrubs, support the birds and insects in abundance, and the Sorrento peninsula in particular is a very paradise for them. The same may be said for many other similar areas along our southern coast, where the consolidated dunes bear a growth of stunted gums, honeysuckle and sheoak, with, near the coast, tea-tree and currant.

CHAPTER X.

A Victorian Ice Age.

In the previous chapters we have dealt only with three classes of rocks—those that have cooled down from a molten state, either on the surface of the ground, as the bluestones, or at a great depth below, as the granites; or, secondly, those formed from deposits spread out by the action of water, either on land or under the sea; and, thirdly, those formed of materials accumulated by wind action.

At Bacchus Marsh we find rocks of still another type, namely, those which have been transported and piled up by the agency of ice. So unexpected was the discovery of rocks of this nature in the latitude

of Victoria that observers, who ventured on the explanation of their formation by ice, were for long ignored or openly derided by their geological brethren. That a land on whose surface ice never lies for more than a few days at a time should have been subjected to the action of great glaciers for hundreds and, perhaps, thousands of years was so improbable that we can excuse people at a distance who doubted, but not so easily critics who, though near at hand, did not take the trouble to look for themselves.

For about a quarter of a century the discovery was practically ignored, and no one thought of inquiring into the evidence, in the only place where it could be tested, namely, on the ground itself. Now we know that the thing is true, and ancient rocks of an ice-formed character have been recognised, in many parts of Australia, even as far north as the tropic of Capricorn. And not only in Australia have they been found, but also in South Africa, in South America and in India.

The age of the glacier-borne rocks in these widely-separated countries is the same. They are geologically very ancient. We cannot, of course, suggest any term of years, for geologists do not measure time in that way, as they have no precise data to work upon, and only relative ages can be dealt with. We know that they are younger than the Melbourne bed-rock, and older than the Gippsland coal-beds. This we decide by the fossils contained in the rocks.

Fossils are the ultimate court of appeal, and fine-spun theories vanish in the presence, it may be, of

a single one. We can get even closer to the age of our ice-formed or glacial beds, and assert that they are of the same age as the lower part of the New South Wales coal-bearing series, and geologists express this fact by saying that they are of Permo-carboniferous age. Such a term, it will be understood, tells us nothing of the nature of the rocks or their mode of formation, but only refers to their age, and that relatively to others.

The characters which indicate rocks as having been formed by ice or glacial action were naturally first studied in countries where glaciers still exist, and in Switzerland the initial steps were made. Since then the inquiry has been carried on in Greenland, Spitzbergen, Norway, in North America, along the north-western coast, and in New Zealand, and still more lately it has been pushed into Victoria Land in the Antarctic regions.

In the Swiss glaciers which occupy valleys, rock masses are shed from the cliffs above. Some form accumulations on the surface of the ice, and some find their way to the bottom. Here they are still firmly held in the ice, and are scrubbed along the bottom and sides of the valley. Besides this, the glacier incorporates in its mass the old surface soil over which it moves, and plucks great blocks from the solid bottom, for a glacier is a moving river of ice travelling over the ground. In any case an enormous amount of wearing away of the rock takes place beneath the glacier. The rocks gripped in the ice are not rounded like boulders carried along by a stream, but have one or several flat faces ground on

them by being dragged along the valley floor. These faces are rarely even fairly smooth, but are marked by parallel grooves and scratches, caused by the cutting power of harder rocks against which they rub. Similarly the hard masses of the rocky floor have their irregularities ground off, just as though the whole surface had been planed; all soft or decomposed rock is brushed away, and only the unweathered rock is left.

The ice of a glacier preserves its direction of movement fairly steadily, and if a cliff or ledge extend across the line of flow it is ground down by the grit and stone-bearing bottom of the glacier. Suppose, for instance, a flake of rock is forced off in such a way that a little cliff a few inches high is formed, facing up stream, then the ice rounds off the top and sandpapers, so to say, the whole face of the little cliff right to its base. If, however, the little cliff faces down the glacial stream, then its foot is not ground out, but remains sharp. All these points have been worked out carefully at the snout, or end, of many glaciers. There is no doubt whatever that a glacier can so mark both the bed-rock and the transported blocks. On the other hand, we know of nothing but moving ice that will grind the bed-rock in this way.

It is possible to find boulders and blocks of rock with parallel scratches on them, produced by other means than by ice. By earth movements the rocky crust may be broken, and the sides of the crack are often scrubbed against one another, and marked with grooves; or again, similar marks may be produced by a landslip. But in these cases the rocks of the

locality are all of the same kind, for they have not travelled far. A glacier, on the other hand, may travel for many miles over rocks of different kinds, and by the time the end of its journey is reached we may find samples of all the varieties of rocks it has picked up along its path. This has been noted on the Swiss glaciers, and is the case in all glaciers.

When material is carried by rivers into the sea, a more or less complete sorting, according to size and weight, takes place. If the current be strong enough to sweep the boulders along, then it will be too strong to allow mud to settle at the same place as that at which the boulders are left. The mud will travel further, till the current becomes slack enough to allow it to sink to the bottom in widespread sheets; so that, in water-formed deposits, we have banks of gravel and beds of sand or mud laid down in separate places. The finer beds distinctly show that they have been deposited in these sheets or layers, or, in the words of the geologist, they are clearly stratified.

The material brought down by a glacier is simply dropped at the end of its course; great boulders, pebbles, sand and mud are mixed up without any sorting out at all. If the whole glacier disappears, then this mixed-up material will be found over almost the whole of the former extent of ice. Its characters, it will be seen, are distinctive, and we can, with absolute certainty, say that is ice-borne, and not formed in any other way.

The whole thing is settled by a series of observations, and if they are made carefully over a fair ex-

tent of country, we are able to speak definitely. A dispute as to whether a deposit is glacial or not can only arise from the fact that it has not been possible to make the observations in sufficient number and variety. If we can find the characteristic smooth bed-rock, ground, grooved and scratched pebbles, boulders with flattened and scored faces, and jumbled up masses of boulders and clay, then we may be sure of the nature of the deposit we are dealing with.

This seems a long introduction, but it is necessary to show how it is that geologists have decided that in the far distant past Australia had a long and severe glacial period. The great ice-age of Northern Europe and America was a thing of yesterday in comparison, and man was in Europe while its effects were still appreciable, if not before it.

Ice-borne Rocks at Bacchus Marsh.

Within a few miles of Bacchus Marsh there is displayed a series of glacial beds, with such clear evidence of their origin and such wonderful proof of an ice-age in early geological times that amongst geologists in other parts of the world the name of Bacchus Marsh is better and more familiarly known than perhaps any other Australian locality.

The glacial beds may be seen in many places throughout the district. Examples of the ice-ground floor of older rock, the scored boulders and stones, and the unstratified clay, with stones of all descriptions and sizes embedded in it, are common enough.

As might be gathered from the previous chapters,

21.—Gorge of the Werribee River above Bacchus Marsh, cut mainly through the glacial beds, which are shown in the foreground. The wooded hill on the left is formed of the old bed-rock. The straight sky-line in the middle of the picture shows the bluestone of the plains.

river and creek valleys, where running water has cut great trenches through the land, are the places where we must go to study the geology of a district. The Werribee for a few miles above Bacchus Marsh flows through a magnificent gorge, which railway travellers from Melbourne to Ballarat catch a glimpse of when the train has climbed the great bank between Parwan and Ingliston. Here may be seen glacial deposits up to 500 feet in thickness, and towering up in lofty precipices. The magnificent scenery of this gorge seems little known, except by geologists and anglers. It takes a good deal of energy to explore the valley, for it must be done in summer, when the river is low, and at that time of the year the place is as hot as a furnace by reason of the radiation from the valley sides.

About three miles beyond Bacchus Marsh, on the main road towards Ballarat, a creek comes down from the north to join the Werribee. This is the Korkuperrimul, and in the four miles of it north of the main road the whole of the glacial beds are laid bare to examination. There are thick sheets of sandstone, with stray boulders in them, and beds of blue boulder-clay. In one place the tiny stream has cut a deep gash right through the centre of an old volcano, and beds of volcanic ashes and injected sheets of bluestone of all sizes may be seen. The glacial sandstones mentioned are of interest, because in a quarry from which was obtained the stone of which the Treasury at the top of Collins-street was built are to be found almost the only fossils yet discovered in association with these rocks in Victoria. These are

fern-like leaves, of a red, rusty colour, which contrast well with the fawn-coloured rock.

The valley of the Lerderderg, a mile or two above Darley, also shows some fine sections, as do Goodman's and Pyrete Creeks, in the neighbourhood of Coimadai. Everywhere we see the well-marked characters of ice-formed rocks.

Glacial Beds Elsewhere.

Bacchus Marsh is not the only locality where the glacial beds of this age are to be seen in Victoria. Some six miles on the Bendigo side of Heathcote, about Derrinal, the railway passes across a long, narrow strip of them. The variety of ice-borne rocks here is wonderful, and the beds are a veritable mineralogical museum. One block, to be seen on the south side of the railway, as it begins to climb westward from Wild Duck Creek to the plateau above, is known as "The Stranger." It weighs about 20 tons, and is a mass of granite of a kind not yet known elsewhere in Victoria. There is also a very fine example of ground down bed-rock which shows, as do all the similar examples yet found, that the ice-movement was from south to north.

There are several other places in Victoria where the glacial beds are shown—from Coleraine, in the west, to near Beechworth in the east. Tasmania, South Australia, West Australia, New South Wales, and even Central Australia, all tell somewhere the same tale of a period of intense cold, when a large part of Australia was as heavily ice-bound as is Vic-

toria Land in the Antarctic to-day, where the ice-sheet is several thousand feet thick.

The land which gave rise to the great Australian ice-sheet has now, for the most part, disappeared. Dislocations of the earth crust have lowered it beneath the sea. At what geological period it sank we do not know, but some of it, at any rate, was still left when the mass of the Otway Ranges was built, though in those times the climate was completely changed. The fossils of the Otway rocks show us that ferns grew luxuriantly, shellfish lived in the muds and strange fish swam in the waters.

In conclusion, it may be mentioned that Australia shows evidence of several glacial periods, though exactly how many there were is not yet decided.

CHAPTER XI.

"On the Road to Lorne."

In travelling from Melbourne to Lorne we pass through several types of country, each characterised by its own vegetation, which reflects in a marked manner the character of the soil and the nature of the rock beneath the surface. This is true, of course, in a broad way, for local conditions, such as those affecting drainage, may alter the features of a small area, and so bring about a state of affairs which favours one group of plants rather than another. On

a journey by rail and coach we have but little time to examine the ground closely, and so we have to trust more to the plants to tell the tale than we should if we were making a leisurely survey.

On leaving Spencer-street station we run quickly over a small tongue of the Yarra delta, being carried on an embankment laid across the brackish marsh. The line of cliffs that bounds the delta at its inner end can be very clearly seen from the train. Almost immediately on crossing the Saltwater we plunge into a cutting in bluestone, and rapidly climb from the level of the delta to that of the bluestone plain. From here to beyond Newport the soil produced from the decomposition of the rock is thin, and bare rock crops out everywhere in boulder-like masses. Then we run down-hill to Laverton, still keeping on the plain. The bluestone is now covered for some square miles by a sheet of mud and shells, showing that the sea bottom has been recently raised, and a shallow bay transformed into dry land. Then follow some miles of typical bluestone country, crossed by shallow winding watercourses, and almost entirely devoid of trees or shrubs, except where they have been planted by man.

On nearing Werribee the soil changes to a coffee-coloured sand, with a fair amount of clay in it, and consequently spoken of as loam. This is the flood-plain of the Werribee, and represents the waste brought down by the river from its upper reaches about Bacchus Marsh, and spread out over the plain before the stream had cut its deep gorge down into the bluestone. At the railway bridge over the river

a great thickness of the loam can be seen. The soil is fairly rich, and from this fact, as well as from its level nature, the district was chosen by the Metropolitan Board of Works as the site of its sewage farm.

About Little River the loamy covering to the bluestone soon disappears, and the plain is once more a lava one. The only naturally occurring trees are she-oaks, which sparsely dot the landcsape. A few miles to the west rises up the granite mass of the You Yangs to a height of over 1100 feet. Like all the granite masses in the drier parts of Victoria, it is scantily clothed with timber, consisting of trees quite distinct from those found on the bluestone. Between Little River and Lara is an area of land which suffers from deficient rainfall. It is as dry as Pyramid Hill, to the north of Bendigo, and, curiously enough, several mallee plants grow hereabouts. Probably the desiccation is caused by the sheltering influence of the You Yangs.

In the neighbourhood of Lara we notice many limekilns, and along the banks of the creek the outcrop of bands of white limestone can be seen. This limestone has been laid down in fresh water, as its fossils tell us, and is of no very great extent. The soil is rich, but, as is frequently the case in limestone regions, is dry, for the porous character of the underlying rock rapidly drains it. Consequently, we have no trees. It is curious to compare the bluestone plain with the limestone country in this respect. They agree in being treeless, and from the same cause, namely, deficiency of moisture in the soil. In the case of the bluestone, the water cannot soak into the dense

rock beneath, and so be stored up, and in the case of the limestone it drains away as rapidly as it is poured on, and is carried out of reach of the plants.

From Lara to Geelong the railway, for most of the distance, passes over a plain resembling in some ways the sandy coastal plain of the Melbourne district. The geology of Geelong is too complicated to be treated cursorily, and we must pass it by for the present.

On emerging from the tunnel, near South Geelong, we find ourselves on a plain covered by a layer of sand, which soon disappears as we approach Breakwater, and once more we find ourselves on bluestone. On our right rise up the Barrabools, barring our way to the westward, and necessitating a long sweep of the railway to get round to the south of them. The hills are composed of sandstones exactly like those of Lorne, and of the same age.

About Connewarre we begin to climb from the low-lying bluestone plain on to a plateau lying to the south of the Barrabools. This plateau we reach just beyond Germantown. It is our old friend the coastal plain once more—a sandy country fairly well covered with rough-barked gums, honeysuckle and she-oaks. Inside the railway fences the tall nutritious kangaroo grass grows well; outside this the cattle and sheep have eaten it out, and poorer grass alternating with small sword-grass is found. The sandy soil lends itself readily to the formation of gullies, and these may be seen on every hillside.

Soon we see the old worn cone of Mount Moriac rising up to the north-west. It is an extinct volcano,

and all trace of its crater is gone. The sandy plain on which we are travelling extends as far as Winchelsea, and sweeps northwards down the Barwon Valley for some miles. On crossing the river near the station we find ourselves once more on the bluestone plain. It sweeps north to the horizon—an almost treeless, stony waste.

To the southward the Otway Ranges now begin to stand up clearly above the plain. A few miles further, and two isolated hills to the northward catch our eye—Mounts Gellibrand and Hesse. They mark the sites of old volcanic vents, and call to mind an early tragedy in Victorian exploration.

At Birregurra our branch line turns southward. We leave the bluestone, and begin to cross the Barwon Valley. The river itself is here a tiny stream, and we pass over it on a long pile-bridge that spans the marsh. Then finding a tributary creek coming in from the southward, we follow it to Dean's Marsh, where our railway journey ends.

We are now, after eight miles, well across the valley of the Barwon. The stream and its tributaries have carved out a great, wide valley, and must have been a long time at the work. The rounded bluffs that project into the valley are in some places, as near the Birregurra church, full of fossils resembling those previously mentioned as occurring in the shaft at Altona Bay and near Mornington. The beds containing them were formed beneath the sea, and by their presence throughout the Western district we know that the sea spread westward from Geelong to Portland, and north to the flanks of the Great Divid-

22.—Coast near Lorne formed by lake sandstones. The shore platform is washed by the waves only during storms. The Lorne pier is at the seaward end of the point in the distance.

ing Range. In this sea the Otways stood up as an island, as we shall see later.

On leaving Dean's Marsh the coach road begins a long and steady climb. The soil is sandy, and quartz gravel at times appears. These sandy beds we have been passing over, and in which the coal of Dean's Marsh is found, are probably the same age as the Altona Bay lignites. This series of rocks rests up against the north-eastern flank of the Otway Ranges, and partly on top of them. On the coast it may be seen from Airey's to Point Castries or the Devil's Elbow, and from here it sweeps far inland.

A mile or two before we reach the neighbourhood of the coal mine, we see massive sandstones in the tramway cuttings, which are of a different character from the loose sands. These may be called the Lake-sandstones, and they build up the main mass of the Otway Ranges. The rich soil formed by their decomposition, aided by the heavy rainfall, supports a dense forest of tall, straight-trunked trees. Between the deserted coal-miners' hamlet and the sharp rise before climbing up to Benwerrin, we pass through vegetation that is strikingly different from what we have seen for some time. The road is white and sandy, trees are stunted, and bright flowering bushes are plentiful. There are many patches of such sandy soil with the same peculiar vegetation scattered throughout the ranges. They generally occur as caps on the hills, and are really much denuded fragments of an ancient sandy plain which must have covered a great part of the ranges, if, indeed, it did not cover all. Another patch, though not so well marked, may

23.—Cumberland Valley, near Lorne, Castle Rock (400 ft.) on the right. The steep slopes show that the valley is new.

be noticed just as the coach road begins its great descent to the coast of Lorne, and here, as everywhere else, it bears its own characteristic plants.

Along the coast about Lorne itself many geological points of interest may be seen. The rocks are composed of compacted sand and mud. A coarse sandstone crops out near the creek just beyond Dolway's on the beach, and fine shales occur at the foot of Castle Rock, on the Cumberland.

Fossils, in a recognisable condition, are scarce, but flakes of vegetable matter abound, and occasionally we can recognise the imprint of a fern leaf. A few casts of mussel shells have been found, but they are very rare.

The beds are of freshwater origin, and were probably deposited in an enormous lake extending from about Casterton as far east as Traralgon. In Gippsland they are rich in coal, but in the Otways themselves coal seams of any useful thickness have not been found. There are thin sheets in the cliffs which the track works along just before we reach the Phantom Falls, and another seam occurs on the beach about fifty yards from the rifle butts at the foot of Mount St. George.

In many places on the beach, as at the southern base of Teddy's Look-out, and in the cliffs, are to be seen brownish, rounded masses embedded in the grey or greenish sandstone. Some look like gigantic cannon-balls, others like enormous potatoes, while in other cases the masses seem to run together into irregular sheets. They have been formed in the rock itself since it became solid. They are not included

boulders, and differ only from the surrounding material by containing more lime and iron-rust, which have collected together by what is called concretionary action, though of course the name does not explain it, and as yet not much is known of the real cause of their formation.

The path to the Cumberland, after passing Sheoak Creek, travels up a wide valley with gently sloping sides. Valleys are generally cut out by running water, but this valley is now a dry one. Its creek has disappeared. As a matter of fact, it is the old Cumberland valley. The river took a short cut to the sea, and its waters having a steeper bed to run down rapidly deepened its channel till it now flows past the cut-off end of its old bed, and somewhere about a hundred feet below it.

The view from Mount St. George is full of interest. Aided by a little scientific imagination we can mentally fill in the valleys till we have levelled all with the highest ranges, and see again the broad plateau which ages of rain and river action have carved into the maze of hill and valley we see spread out before us like a map. Mount St. George itself, about 520 feet in height, is capped by a small deposit of red sands, which show that even here the coastal plain of the Melbourne district is still to be traced.

The numerous waterfalls and rapids in the streams, and the rocky walls of so many of the valleys, show us that the river system is, as geographers term it, "new"; that a comparatively recent elevation has taken place, and that the rivers have not long been at their task of reducing everything to a dead level.

24.—View from Mount St. George, near Lorne, looking north-westerly over the basin of the St. George River.

It is this fact, combined with the copious rainfall, the rich soil, and the trend of the backbone of the ranges, that makes the country the beautiful place it is. Hot winds cannot scorch it, as it lies under the lee of a great wall; the "new" valleys steep-sided, dark and cool, yet sheltered from frost, are a paradise to the lover of plants, and their beauty loses none of the charm when we seek to inquire into the reasons of its being.

CHAPTER XII.

The Otways as an Island.

Travellers by rail on the western railway will remember how, when they approach Winchelsea, they see the Otway Ranges rising up to the southward, and that not till they pass Colac do the hills die away. The railway itself from Winchelsea to Warrnambool for almost the whole distance lies across a vast bluestone plain, over which are dotted the low, isolated hills, that mark the points whence came the lava and volcanic ashes that form the level country. On a clear day, away to northward can be seen the dim outline of the Dividing Range, which forms the great water-parting of the State.

Looking at the isolated mass of the Otways, we might perhaps suspect that it was once separated from the northern land mass by a sea, in which it stood as an island. But suspecting a fact is very

far from proving it, and the proofs of the former insular conditions of the Otways have been gradually accumulated since the first suggestion of the truth nearly half a century ago.

As we have had occasion previously to remark, the relative ages of rocks may be determined in two ways. If we find one series of rocks resting on another, then the underlying is the older. Thus there are sand patches lying on the top of many of the hills of the Otways. They are quite distinct from the main rock mass, and must be younger than it is But if two areas of rocks are separated, we must use another test, which is not quite so simple. This is supplied by the fossils, and can, of course, only be used for rocks containing them.

The Use of Fossils.

Since life began on the earth there have been continual modifications in form and structure of both plants and animals. The older the fossils are, the more unlike are they to those of more recent times. Old forms have died out, and new ones have come into existence. The establishment of the orderly sequence has been the result of many years of careful observation, and was discovered long before evolution was accepted as its explanation. By comparing the fossils of the rocks of our goldfields with those of other parts of the world where similar ones occur, their approximate relative age has been determined. Similarly, a conclusion has been come to as to the age of the rocks forming the Otway Ranges, and it is known that they are very much younger than

those of the goldfields. We might, on other grounds, arrive at this conclusion, but the fossils prove it for us, for in no part of the world do we find fossils at all resembling the Otway ones in rocks older than or as old as our goldfield rocks

Besides using fossils as a test of age, we may judge from them the physical conditions under which the containing rocks were formed, or, again, may study them as links in the chain of evolution. As indexes to the physical conditions we can usually readily distinguish those that live in fresh water from those that dwell in the sea. But we must not judge from single specimens, but from the whole set of fossils. Thus a flood may carry land-dwellers and those living in fresh water out into the sea where their remains may be preserved. In deciding questions arising from the presence of fossils we must use our judgment. The fossils must not only be collected, they must be studied with the intelligence derived from a wide knowledge of them.

THE FLOOR OF THE STRAIT.

We have, then, two sets of rocks, those forming the great mass of the Dividing Range, which are very old, and the outlying mass of younger rocks, which constitute the Otway Ranges. But there is another set as well, which is younger than both, and does not form high ranges, as nowhere in Victoria does it occur more than 500 feet above the sea. To these younger rocks we must pay a little more attention for our present purpose. They are of marine origin, for they are in most places very full of fossils which

live only in the sea. They therefore indicate that where they now are found the sea once flowed. As these fossils are plentiful and well preserved they have been extensively collected and studied for many years past.

One of the richest collecting grounds is at Muddy Creek, a few miles from Hamilton. Here we may gather hundreds of different kinds of shells, as perfect as though they were just picked up on the beach. But they differ from those found in the seas of today. Almost all are extinct, though a fair proportion very closely resemble existing forms. Their nearest allies seem to live in warmer seas than occur in the same latitude at present, so they indicate that there has been a cooling of the climate since they lived.

In size and beauty of form they far surpass our present Victorian shells, but what their colours may have been we do not know, for almost every trace is gone; yet doubtless they and the associated fossils of other kinds were as gorgeously painted as their existing allies. There are cowries of many kinds, some larger than the top of one's head, others as small as the little ribbed-spotted cowrie now found on our beaches. Cones and volutes are even more varied, and hosts of less familiar shells abound. Sea-eggs, corals, fragments of starfish, teeth of sharks, and, in fact, the remains of all sorts and conditions of sea-dwellers, are found in a profusion so great as to be bewildering, and it may safely be said that nowhere in the world is such a wealth of fossils preserved. Their study will afford material for

workers for many a day in spite of all that has been done, though this is not a little. The fossils show us that the beds are of the same age as those found in the borings at Altona Bay.

25.—Map of the Otway district and the country to the north. The lake sandstones, which formed the Otway Ranges (now 2,000 ft. high) stood up as an island in the sea in which the rocks of the coastal plain were laid down. The bluestone to the north covers a large area of these marine coastal plain beds.

These fossils, then, prove beyond a doubt that the country through which Muddy Creek now flows lay beneath the sea at no very distant time geologically. But we find the same fossils in many other places, and must conclude that here also similar conditions prevailed, and that the beds are of marine origin.

Throughout the Western District, from Geelong to Portland, wherever the rocks below the bluestone are exposed along the courses of streams, as the Barwon, Moorabool, Leigh and Hopkins we find the same beds. In other places wells and borings have yielded enough material to show that here also the same beds occur as for instance near Corangamite, Camperdown, Hexham and Heyfield. Further south, in the valleys of the Heytesbury forest and along the coast from Warrnambool to the mouth of the Gellibrand River, the same story is told; we are walking over an old sea-bed, which is of more recent date than the formation of the Otways. Near Cape Otway and Cape Patton, and along the coast from Airey's Inlet to Bream Creek, we find patches of the same beds, which show that the sea at the time of their formation flanked the Otways on their southern and eastern sides, just as it did on the northern and western.

Depth of the Strait.

So far, then, we have evidence of this former sea all round the mountain mass, but we have to consider the question whether it covered it entirely. In many places in the Otways, up to a height of over 1000 ft., there are patches of sand and gravel, capping spurs, but as far as our present knowledge goes, they do not cover the highest hills. They do not, as far as is known, contain marine fossils, and very seldom any fossils at all. Then, again, we do not know any place in Victoria where fossil-bearing rocks, similar to the Muddy Creek ones, occur more than 500 ft. above the sea, and the highest ones we

know, which are near Maude, just east of Lethbridge, on the Geelong to Ballarat railway, were clearly formed near a shore-line. So that it appears that the Otways must have stood up as an island some 1500 ft. or more above the sea which then surrounded them.

A subsequent elevation of the land took place, and raised the old sea bed above the ocean level; and some considerable time after this there occurred the volcanic outburst which covered the greater part of the western plain with its layers of bluestone and ashes. Those parts of the Western District which were not covered, such as a large area west of Hamilton, about the Glenelg, and another patch near Hexham, are mostly sandy country, and not so valuable for agriculture as the surface occupied by the volcanic rock, which has decomposed to form the rich soil for which the Western District is so well-known.

At the time when the Otways were an island the same conditions probably prevailed in South Gippsland, which was separated from the Continent to the north by a broad strait, along which the Gippsland railway now runs. Fossil-bearing rocks showing the former extension of this sea underlie Sale and Bairnsdale, and a large area south-west of Sale. In Western Victoria the same beds run round the hill country of Dundas, and underlie a great part of the Wimmera District, passing far into South Australia, and an unknown distance northward under the river-plains of New South Wales. At the time of their formation the coast line of Victoria must have been very different from what it is at present, and its

former position we can trace by mapping the line along which marine fossils cease to be found on the coastal plain.

CHAPTER XIII.

By Rail to Bendigo.

The aim of the engineer, who lays out a railway from one place to another, is to choose the most direct, and at the same time the easiest route. Sometimes he finds it cheaper to travel round a range of hills rather than to traverse it by the aid of high embankments, deep cuttings and tunnels; sometimes, again, he prefers to skirt a deep valley for miles rather than cross it at once by a long and costly viaduct. The course of the line then is governed to a great extent by the geographical features of the country through which it passes, and these features are largely due to geological causes.

During a trip by rail, if we carry a good map with us, and more especially if that map be a geological one, we can easily see the reason for many of the divergences from a direct line, but we can learn a great deal more if we walk over parts of the surrounding country.

On leaving Melbourne by the Bendigo train, as soon as we have crossed the Saltwater River, we climb on to the bluestone of the Keilor plains. These are, as we have seen previously, treeless, desolate and

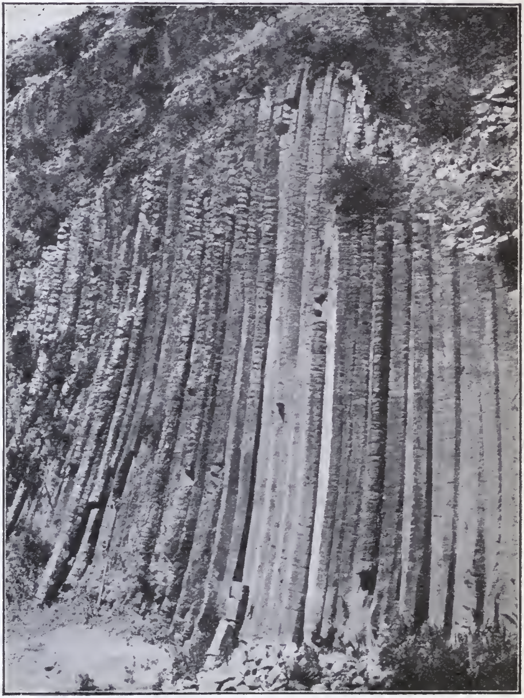
stony. The greater part of the bluestone forming them seems to have come from volcanoes to the north, and especially from a group near Sunbury. There is a long gradual ascent as we approach that township. In the twenty miles from Footscray to Sunbury we rise about 700 feet, on a gradient which represents, fairly closely, the old sloping surface of the bluestone as it flowed steadily down hill towards the sea.

There are a few watercourses cut by the streams, but only one is of any depth, and this we catch sight of about a mile to the east of the line between Sydenham and Diggers' Rest. It is the valley of the western branch of the Saltwater or Jackson's Creek, and just where we see the edge of the valley from the train are to be found, deeply hidden in the gorge, some splendid bluestone columns, known locally as the Organ Pipes.

On approaching Sunbury, on both sides of the line, there stand up several dome-shaped volcanoes. The rich soil formed from the decomposition of these old cinder-heaps is in many places cultivated, sometimes being covered by vineyards. One of the hills to the west of the line has been named Mount Tophet by some one who looked back to the time when the plains were covered by a seething flood of melted rock. But strangely enough the hill bearing the name is not volcanic, but is formed of the old bed-rock, and is the only hill in the neighbourhood which did not contribute its share to the devastating flood which so completely altered the whole surface of the district.

Soon after leaving the Sunbury station we see the

old bed-rock, consisting of slates and sandstones tilted on edge, showing in the cuttings, and then



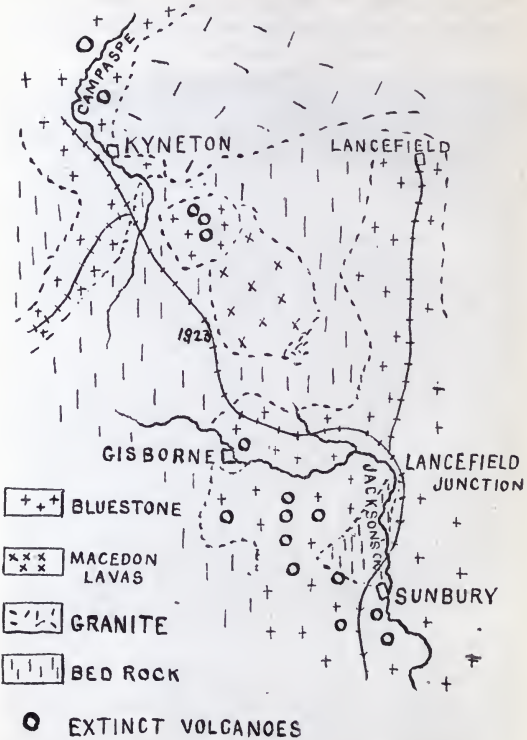
26.—"The Organ Pipes," Jackson's Creek, near Sydenham. The bluestone on cooling has contracted to form columns. These are 60 ft. high. (Photo. by Mr. H. J. Grayson.)

crossing Jackson's Creek we begin a short, sharp climb on to a plain lying at a higher level than the Keilor plain that we have just left.

Jackson's Creek is sometimes known as the Gisborne Creek, or as the right branch of the Saltwater, the junction with the left branch which comes down from near Lancefield taking place near Keilor.

The plateau on to which we have climbed is another bluestone one and it stretches away to the north beyond Lancefield. The railway, which hitherto has had a north-westerly direction, now bends to the northward and we can see the western flank of Macedon, round which we have to pass, far away to the left of the line. Close beside us on the west is plainly seen the reason of the change in direction of the line. Jackson's Creek has cut a wide valley, deep through the bluestone and far into the bed-rock. To avoid this valley which bars our direct approach to Macedon, the line keeps to the bluestone plain, and curves gradually to the westward with the curving valley till we come to Riddell's Creek. Then strangely enough our great northern line bends still further, and for a little way runs south of west to escape the hills to the northward. Near the Gisborne station we leave the bluestone at a height of about 1500 feet above sea level.

As we have approached the Dividing Range the annual rainfall has increased, and trees have been able to grow on the bluestone to a slightly greater extent than they do to the southward, but still not so thickly as they do on the old bed-rock hills north of Riddell.



27.—Map of the country bordering the railway line between Sunbury and Kyneton, showing the great curve in the line to avoid the deep valley of Jackson's Creek.

The township of Gisborne, or, as it is sometimes called, Old Gisborne, we cannot see from the railway, for it lies two miles to the south of us in the deep valley of Jackson's Creek. This has been carved out by the stream, and floored by a rich alluvial deposit of loam derived from the mingled waste of rocks of many kinds.

The line leaves Gisborne and turns north-west, and we climb a hundred feet to the mile for the next five miles. The country has entirely changed its character. It is no longer level, but its surface is scarred by steep valleys that wind in all directions. We are on the old bedrock, and beds of sandstone and slate, of various shades of yellow, red and purple show their upturned edges in the railway cuttings.

The whole country is densely timbered, and in the old days, before the railways, the gullies and ranges of the Black Forest were the scene of many a bushranging episode, for through it lay the road from the goldfields of Bendigo and Forest Creek.

To the right of the line rise up the steep slopes of Mount Macedon, 3500 feet above the sea and 1500 feet above the line. The rocks of which it is formed differ from any that we have yet had to do with. They are of igneous origin. Mount Macedon, high as it is, represents the worn-down stump of an ancient volcano, and consists of sheets of lava and cinder-beds, but the rock is entirely different in composition from bluestone, and is much older than any of the bluestones we have dealt with. The variety of rocks is great, and there is no popular term applied to them as a whole, while the scientific ones are

numerous and usually long. We may then speak of them as a whole as the Macedon lavas, though some are not lava.

The hills are richly timbered because the rocks are much decomposed, and the heavy rainfall supplies abundance of moisture for plant life.

At 1900 feet we cross the low saddle in the Dividing Range, still running over the bed-rock which continues almost as far as Carlsruhe, and then we again enter on bluestone country. This continues to Taradale. The soil bears a rich growth of trees in many places, and, especially about Kyneton, is extensively cultivated, for the rainfall is abundant.

Away to the westward we see the rugged, forest-clad ranges of a great area of bed-rock country, and after passing Taradale we travel for a short distance over it, and then cross the corner of an extensive granite patch. Looking to the north-east, we see stretching into the distance, the sparsely-wooded hills so characteristic of granite country except in regions of heavy rainfall. Even at a distance the hills thus display their geological nature by the character of the vegetation they bear.

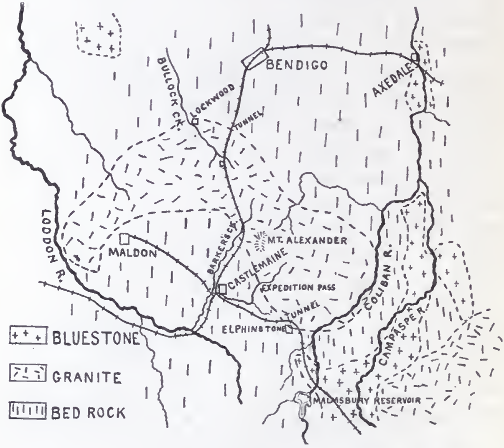
Those who have examined the granite about Elphinstone tell us that it has sent sheets into cracks and between the layers of the bed-rock. This of course shows that the granite is the younger of the two sets of rock. Not only has the granite behaved thus in a way that shows us that it was once quite plastic, but it has had a marked effect on the bed-rock for some distance, say a quarter of a mile, from where the two are in contact.

The plastic, or molten, granite was intensely hot and the great heat has altered the slates and sandstones considerably. Apart from changes in their structure they have been much hardened and have thus become more resistant to the action of weathering. The result is that all round the granite area we have a wall-like ring of hard rock standing high above both the unaltered bed-rock and the granite, both of which have been more easily removed by rain and wind. In some places streams, rising on the granite, have cut through the wall, and by following up the stream we can pass easily from the bed-rock to the granite. Near Elphinstone again, the Coliban has worked along the line of contact of the two rocks and has cut the wall away, so that for some distance the stream flows over a granite bed, and it is not easy to say exactly where the junction of the two rocks is.

We are, it will be remembered on the granite, and if the railway engineer wanted to travel direct towards Bendigo he could have carried the line for many miles without much difficulty. But he had to make a sharp turn to get to Castlemaine, which lies some eight miles to the westward and he had found it easier to come through Taradale because the long strip of bluestone gave him an easier path than he could have found through the rugged ranges to the west.

To get from the granite at Elphinstone on to the bed-rock it was found necessary to pierce the hardened wall described above by a tunnel. A few miles to the north of Elphinstone Forest Creek, which rises

on the granite, has cut a gorge through the wall. This gorge is known as Expedition Pass, because through it in 1836 Major Mitchell found his way with his exploring party. But this pass was unsuitable for the railway as once through it rugged ranges lay beyond.



28.—Map of the country bordering the railway line from Malmsbury to Bendigo. The crescent-shaped area of granite is surrounded by a wall of hardened rock through which tunnels were necessary.

Passing through the Elphinstone tunnel the railway finds its way down a tributary gully to Forest Creek. It keeps on the south side of the valley, now passing through deep cuttings in the bed-rock and again running over the old gravel-beds formed by

the creek before it had shifted its course more to the north and lowered its bed to its present level. At Castlemaine, Forest Creek meets Barker's Creek coming down from the north and the two streams flow together as Campbell's Creek, south-westerly to join the Loddon.

The Castlemaine station lies 1000 feet below the saddle by which we crossed the Dividing Range, and is 900 feet above the sea. The railway now turns northward direct towards Bendigo. We travel up the valley of Barker's Creek, passing sometimes over the bed-rock, and at others over the great gravel-banks which mark out the old course of the stream, which has shifted to the westward and cut deep below its old course. The country is thickly covered with dark, rough-barked gums and hill and dale succeed one another rapidly.

Barker's Creek rises on the granite country to the north-east of the line, and in its course has cut a wide, open valley through the hardened wall of bed-rock which, as we saw, borders the granite area. There is then no obstacle to the railway passing from one set of rocks to the other, and soon we find ourselves in country of a different character. The timber is not so dense, the gums have a lighter coloured and smoother bark, and, if our visit is in the spring or late autumn, there is a rich growth of grass, which is characteristically almost absent from the bed-rock area. Most of the hills have a gentle slope and the valleys are wide and flat bottomed. Still there are some lofty heights to be seen. To the eastward, Mount Alexander rises up boldly, and

shows great faces of bare, grey rock. To the north of this Mounts Barker and Sargent are similar though not so high. Here and there, even on the flats, the grey, rounded masses of granite show through the thin, sandy soil.

Gradually the line climbs up through a deep cutting to the top of a long, low range that runs east

29.—Granite tors on Gellibrand's Hill, near Broadmeadows.

and west, and is known as the Porcupine Ridge. This was a name of ill-repute in the old coaching days, when the inhabitants were not as law-abiding as they are now. From the Ridge there is a long, steep descent of about four miles to Ravenswood, and, with steam shut off and the brakes hard down the distance is soon passed over.

While travelling over the granite country, we may try to realise that granite is a rock formed only at a considerable depth below the surface, under enormous pressure. Some say that the depth required was several miles. For granite to appear at the surface then, thousands of feet in thickness of overlying rock must have been removed by the action of wind and rain. The surface of the granite, as we see it, is carved into hill and valley by the action of the streams, and Mount Alexander itself is but a larger block left standing while the surrounding rock has been removed particle by particle. The mind is totally unable to grasp the length of time that must have elapsed since this great sculpturing began. Generations of men might come and pass and no appreciable difference be seen in the rocks, and yet the immense changes have been brought about by slow action through the course of ages.

The soil produced from the decomposition of granite is poor and light, but as it is fairly thick in places, and, as the subsoil is deep, a fair amount of water is held in reserve, and though cereal crops do not grow well, yet the Harcourt orchards are not unknown in England.

Ravenswood lies in a valley down which pass the upper waters of Bullock Creek. The stream cuts through the bounding wall near Lockwood, and flows north past Marong. The railway running north from Ravenswood can find no outlet through the hardened wall that rises up as Big Hill and Mount Herbert, and passes through it by a tunnel. So that both the Elphinstone and Big Hill tunnels owe their neces-

sity to the same cause. The bed-rock, baked and hardened by the granite, stands up like a wall, while the unaltered, softer rock and the more easily decomposed granite have worn away, and through this wall the railway tunnels go.

On leaving the tunnel the line enters the upper part of the Bendigo Creek valley, and rapidly runs down hill to Kangaroo Flat. The waste from the highlands to the southward has been carried north by the streams, which dropped, first their load of gravel and sand and then spread out the clays over a wider area. The valley is fairly broad, and is hemmed in by the ridges of bed-rock we see rising on both sides of the line. When we get to Bendigo itself the bounding hills are Quarry Hill and that on which the Cathedral and the gaol stand.

At the mouth of the valley, where the old hills sink down to the plain stand some great gravel heaps, known as White Hills. Their tops were once the bed of the creek and on both sides of them rose the bounding hills which have now disappeared. The cap of gravel protected the bed-rock under it from attack, so that they, with their sheltering coat, now stand up as evidence of the waste that has gone on.

The country about Bendigo, where the great part of the surface is covered with a thin soil derived from the bed-rock, is, as we should expect, poorly covered with vegetation. The high land to the south robs it of its fair share of the rain that has passed the Dividing Range, while it has no protection from the drying northerly winds. Man has brought about

many changes. He has cut down all the timber over large areas of country, and by silt has choked the creek beds and killed off the natural vegetation of the flats. But the soil of the flats is rich in plant food, and with a good supply of water they respond richly to the work of the gardener and orchardist.

30.—Looking south from Bendigo. The range of hills on the horizon is the hardened wall round the granite. Mount Alexander (granite) is seen on the left.

A few miles to the east and west tongues of the southern bluestone run north, and near the Loddon and at Axedale, rich soil, formed from their decomposition, show in marked contrast to the rest of the country.

About twenty miles north-east of Bendigo, the railway line leaves its last patch of the old bed-rock

near Goornong and passes on to the northern plain, where the underlying rocks are hidden by the waste brought down by the rivers, and spread out as an immense level deposit. This great sheet of sand and silt, forming the flood-plain of the Murray basin, is an important feature of inland Australia.

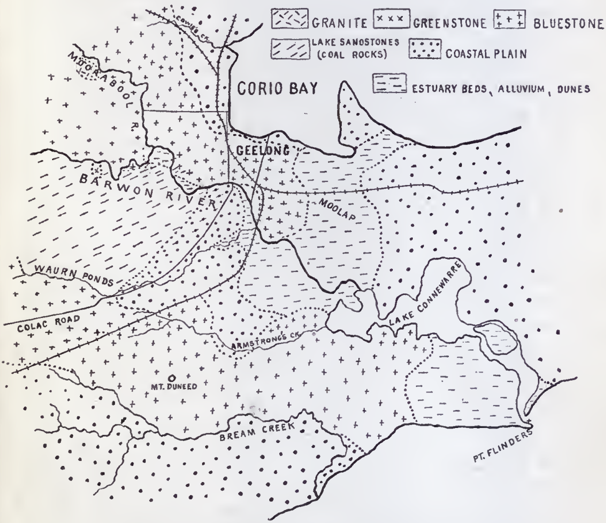
CHAPTER XIV.

RAMBLES ROUND GEELONG.

If we take our stand on the highest part of Newtown Hill, say in Noble street near the Geelong College, or better still, if we are not afraid of a walk, on Fisher's Hill near Ceres, we see a wide panorama spread before us stretching from the south through the east and so to the north and north-west. Perhaps our first thought is the great extent of the view, which embraces the yellow sand-hills of Bream Creek and Barwon Heads, the hills of the Bellarine Peninsula, the blue of the wide-flung bay, and the level plains of its northern shore broken by the wooded heights of the You Yangs and the Anakies. Looking a little more closely we see that excepting for the hills mentioned, it is really a great plain, stretching from Bass Strait to the flanks of the northern hills. To the westward there is a change, for the beautiful outlines of the Barrabools block our view in that direction.

A new fact next attracts our notice, Geelong's great

failing, the dearth of trees. The plain is essentially a bare, open one; the Barrabools themselves are devoid of timber and it is only in the far distance near the sea-coast or beyond Leopold that the dark foliage



31.—Geological map of the Geelong district.

of the gums catches the eye. It is true, of course, that man is responsible for this in part, that old inhabitants tell us tales of being lost in the red-gum forest about South Geelong, that Moolap was fairly well wooded in the past. But other agencies besides

the axe are answerable for this widespread area of grass country instead of woodland.

The main cause is the want of water, both lack of rainfall and deficiency in the soil, and both these factors are in a sense geological. The Otways, with their heavy rains, probably deprive Geelong and a good deal of the country to the west, of what should be their share. With regard to the deficiency in the soil, we shall speak of this when we have noted some features in the rocks of which the neighbouring district is built. If this were a systematic treatise we should describe the oldest rocks first, and then deal in due order with younger and younger ones till we came to those whose formation we can see going on before our eyes, but perhaps it will make the subject more interesting, though less exact, if we take the leading scenic features, and discuss the rocks of which they are built and the forces which moulded them to their present forms.

The Barrabools.

Undoubtedly the picture-spots of Geelong are to be found amongst these hills, and few more charming drives can be found than that up through Highton to Ceres, and then on to Gnarwarre, returning by the Colac-road, past Mount Moriac and Pettavel ; or else striking south from Ceres down the steep hill to the Valley of Waurn Ponds direct to Pettavel and so home. The main mass of the hills is composed of a soft brown sandstone. This we can see in all the road-cuttings in the district. Occasionally there are thin beds of mudstone or shale. Near Ceres are the

32.—Devon Valley, Barrabool Hills. The straight sky-line shows that a platform has been dissected.

large, old quarries which yielded the stone to which Geelong owes so many of its beautiful buildings, the Town Hall, many of the banks and the Free Library. Sandstones and mudstones such as these were laid down in water into which the waste of the old land was swept by the streams that drained its surface. Similar rocks built up the hill-block of the Otway Ranges. They are Victoria's coal-bearing series, though coal is found, as we shall see later, in other rocks.

The same rocks crop out along the foot of the hills to the west of the Portarlington pier and underlie a considerable part of the Bellarine Peninsula.

We judge the age of a rock and a good deal as to its mode of formation by the fossils it contains, and the only fossils found in the Barrabools and at Portarlington are the remains of land-plants and more especially of ferns. There are no traces in these rocks anywhere in Victoria of sea-dwelling animals, so we conclude that they were deposited in a vast lake. We may then call them the "Lake Sandstones."

This lake extended from about Casterton far into South Gippsland. Over a great part of the intervening country all traces of the rocks have been washed away, though they must once have existed there. With few exceptions we know nothing of its shoreline, and one of these exceptions is near Geelong. Large stones are incapable of being moved far from a shore. The streams which roll them along lose their force when they enter a sea or a lake. Sand will be swept further and mud will travel further still. A

boulder-bed, or heavy conglomerate, as it is called, is thus evidence of a shore line, and such a deposit occurs in the Lake Sandstone on the banks of the Barwon about a mile above the falls. Here we find blocks of slate and ancient sandstone, boulders of old greenstone, and large pieces of quartz. This greenstone is an igneous rock, that is, it is the result of the consolidation from a molten condition. Owing to its green colour it was erroneously imagined to contain copper, and a tunnel put into the hill to work the deposit still exists, and perhaps is still known to many as the "Old Copper Mine."

The sandstones of the coal series in most places have their sand grains but poorly cemented by clayey matter, and the result is that they break down into a somewhat sandy soil under the action of the weather. The shales yield a clay and the combination produces the rich agricultural land for which the Barrabools are so famous.

The porous character of the rock beneath the soil drains away the rainwater too rapidly for trees to be able to maintain a hold. They might grow well for a year or two and then a succession of dry seasons would kill them off. We find the same state of affairs about Casterton and Coleraine, where the coal series is treeless and always was so, but wherever the rainfall is heavier, as in the Otways and in South Gippsland, exactly similar rocks to those of the Barrabools carry the dense forests for which those districts are so well known.

An intermittent rainfall or a drïer climate are, however, not unsuitable for the growth of grass. A

33.—Near Gnarwarre, showing the characteristic vegetation of the red sands of the coastal plain.

drought may kill everything off, but seeds lying dormant in the soil spring up in response to the first falls of rain. But some soils are more retentive of moisture than others, and there are areas about Geelong where timber grows well though the rainfall is not appreciably greater.

THE COASTAL PLAIN.

One type of these tree-clad areas is sandy. Generally there is a good deal of red, rust-cemented rock present. The roads are made of this ironstone, and smooth tracks, well suited for light traffic are the result. The great part of the Bellarine Peninsula between Drysdale and Ocean Grove, and west to the foot of Leopold Hill is of this nature. Bracken-covered, sandy patches with low scraggy gums, honeysuckle and prickly box are the chief features of this country. We see the same type to the south-west, from Torquay out past Freshwater Creek and through Modewarre, then up past Mount Moriac and on to the Plateau of Gnarwarre. Northward from here we meet it again, between Teesdale and Shelford, and again on the plateau about Maude. In some places there is less iron in the sands, and the roads are heavy, as about Anglesea. In travelling through these districts there is one feature that strikes us at once. It is plain country; large flat expanses are separated by deeply-trenched valleys, carved out by the intermittent streams which occupy their troughs.

The materials composing these rocks are, in the main, quartz-sand and clay. Inland, as about Gnar-

34.—Near Gnarwarre, showing vegetation of red sands—gums, sheoaks, sword-grass. Mt. Moriac (volcanic) in the background.

warre and Shelford, we find quartz-gravels. The pebbles are rounded from being rolled about by water. In some places we can see that the beds have been laid down in layers, spread out by water action. Elsewhere we find sheets of limestone, composed almost entirely of fossils, as at Pettavel on the Waurn Ponds Creek, at Batesford and along the coast near the mouth of Spring Creek. Where clays are especially abundant, the beds are full of fossils of many kinds, shells, sea-eggs, and hosts of things familiar only to the naturalist. Geelong and the surrounding district is rich in such fossil localities. From Airey's Inlet to the mouth of Bream Creek along the coast, with but few intermissions, we find storehouse after storehouse full of these relics of the past. We see them again in the valley of the Moorabool from Fyansford to beyond Maude, along the Barwon from Pollock's Ford to Inverleigh, and up the Leigh for miles above Shelford. We find them along the western beach from Duck Ponds to the railway pier, and again at Curlewis near Clifton Springs, and yet again from Campbell's Point in Connewarre Lakes to Ocean Grove. Few places can compare with the district in the richness of its widespread fossil beds of this age.

But what, in brief, is the story that these fossils tell? They are the remains of dwellers in the sea, whales and sharks, shell-fish and corals, tiny foraminifera and sea eggs, starfish, feather-stars, sea-mats and hosts besides. They tell us, in language not to be misunderstood, that where they now lie, there rolled the sea, that what is now dry land was once

the ocean bed, swarming with brightly-coloured things, and richer in life by far than the seas that now wash our shores. The sediments that form the great beds of sand and clay were swept down from the high land to the northward that rose above the sea. Some of this old land, we still see, the You Yangs, the Anakies, and the Steiglitz Ranges.

After the beds had been laid down there came an elevation of the land, and the old sea-floor, as we see it, was lifted above the waves. The plain thus formed is of the type known to geographers as a coastal plain, and almost all the Victorian sea-board is of this nature. Since its first appearance as a plain this old surface has been cut into by streams both great and small, and over a large part of its area has been covered by sheets of bluestone.

THE BLUESTONE PLAINS.

Bluestone, such as is used for road metal in all the country round, is a rock of an entirely different nature from the water-formed rocks that we have been considering. It has been melted by the earth's internal heat, and while in a molten condition has poured forth and flowed over the surface of the ground. It is then a lava, such as can be seen welling forth from the active volcanoes of the present day. As it was liquid when it appeared on the surface it would find its way slowly along the old valleys, filling them up and spreading over the flat country in wide sheets.

The nearest old volcano to Geelong, now only a worn-down stump, is Mount Duneed. Its lava poured

35.—Looking north-east from Mount Pollock over the bluestone plain dotted with sheoaks.

out chiefly along its southern flank, filling up an old valley as it flowed eastward. It spread wide over the country across which the Bream Creek and Barwon Heads roads run, and probably entered the sea. It has thus formed a great bank to the southward of the Bellarine Peninsula and the rock can be seen in many places from Bream Creek to Mount Colite. In this way a broad bay was formed which is in course of being filled up by the Barwon, and the last remains of which are known as the Connewarre Lakes.

Mount Moriac and Mount Pollock are also old volcanoes, as are also the three Anakie Hills. There are, however, widespread sheets of lava, the origin of which we are at present unable to refer to any particular volcano, such as the flow from Windmill's quarry at the west end of Noble-street. This runs to the river near Prince Alfred Bridge, and down stream on the north bank. How much of the South Geelong flat it underlies is not, I think, known, but it can be picked up at intervals to the Breakwater.

The crest of almost all the high land about Newtown Hill and thence past Christ Church, and so out on to the Portarlington-road at the south-east corner of the Botanical Gardens is also capped by bluestone. The same rock crowns Herne Hill and runs thence north to the Anakies and east to Corio Bay, near the Moorabool wharf. West of Fyansford the great lava plain of Western Victoria is entered on and this extends, with a few breaks, as far as Mount Gambier in South Australia.

The relationships of the lava-sheets about Geelong is, as yet, an unsolved problem, which I shall not at-

tempt to discuss. We can, however, notice the physical characters of the lava-plains generally. They are devoid of trees, but rich in grass, that is taken as a whole, for there are local differences. The reason of this has been described elsewhere and need not be repeated.

The Granites and Greenstones.

To the westward of Batesford is a small area of timber-covered country with a sandy soil, and all over it we see great blocks of rock rising above the surface in rounded masses. These are mainly granite. The weathering of this rock produces a greyish, sandy soil, fairly rich in plant food. There are interspersed with the granite blocks, especially on the eastern side of the area, masses of a dark rock, which from its colour, we may call greenstone. The soil from this is black and heavy, just like that from bluestone. Another area, very like the Dog Rocks country, occurs near the Ceres Bridge over the Barwon. Patches of granite are to be found up Sutherland's Creek and so on to the Anakies and the You Yangs, but whether any greenstone is associated with these is not, I think, known.

Both the granite and greenstone are rocks which have cooled down from a molten condition under enormous pressure, in other words, at a great depth below the surface, whereas lavas have cooled down on the surface. The depths at which the granites cooled has been estimated by some authors at several miles, so that where they are seen at the surface land must have long existed. The removal of rock can

only take place by the action of rain, rivers and atmospheric agencies generally, and as miles of overlying rock have been removed, immense periods of time must be allowed for the processes to have taken place. The granites of the Dog Rocks then are very old, but whether they are older than the old bed-rock of the goldfields, such as occurs about Steiglitz and Maude, is a point about which difference of opinion may as yet be allowed. The granites and greenstones have nothing to do with the bluestones which are far younger.

It may be mentioned that the greenstone is one of the toughest rocks we have, and its toughness has hitherto prevented it being made much use of commercially, though it is extremely handsome when cut and polished. We find it cheaper to import worked blocks of somewhat similar rock from Scandinavia and North America, and neglect what we have at our doors.

Estuary Beds.

Some two or three miles on the Geelong side of Barwon Heads, the road, after leaving the bluestone plain, crosses a swamp on a long embankment. This swamp is but little raised above the level of the sea, and on the sides of the embankment can be seen a great many sea shells which have been thrown up by the spade. They are such forms as are found in shallow, muddy, protected inlets, and point to the time when the Connewarre Lake was of greater extent than it is now, and when, instead of being brackish, it was a real arm of the sea, with its mouth bounded on the one side by the brown sandstone

36.—Merrawarp road, Barrabool Hills. The straight sky-line shows the coastal plain. The hill behind it on the left is greenstone. The spectator stands on lake sandstones.

cliffs of Ocean Grove, and on the other by the bluestone ridge we can yet trace under the Bluff. We find similar estuarine beds about the Moolap Post Office, and probably Corio Bay was at the time of their formation connected with what is now Lake Connewarre, and the Bellarine Peninsula was an island.

The Sand Dunes.

From Zealley Bay to Queenscliff the most characteristic feature of the coast is the sand dunes. These have been piled up by the wind from the sand, driven ashore by the waves. A close examination of the sand shows that it is mainly composed of fragments of shells and that quartz sand is present only in very small proportion. We see this sand travelling inland, driven in by the steady sea-breeze, till it is conquered by the plants which continually strive to grow on its shifting surface. The old road to Barwon Heads skirted the dunes and for a long distance passed over grassy downs. Gradually, however, owing to the traffic, the surface was broken and the sand began to drift. The road became more and more difficult, and a visit to Barwon Heads was not to be lightly undertaken. Where the dunes are stationary for a long time the sand becomes cemented into a fairly hard limestone, and this old dune rock forms the highland of the Bluff, of Point Lonsdale and Queenscliff.

The Freshwater Limestones.

At Limeburner's Point and Lara we find limestone beds, which, from the nature of the fossils they con-

tain, are seen to be of freshwater origin. Probably the now separated areas were originally continuous, and were laid down in a large fresh-water lake. We find freshwater shells and occasionally the bones of the strange extinct animals, such as the giant kangaroo and Diprotodon which formerly wandered and grazed over the country round us.

The Old Bed Rock.

About eighteen miles north-west of Geelong, in the valley of the Moorabool and of Sutherland's Creek about Maude, just east of Lethbridge, there occur exposures of the ancient slates and sandstones which resemble the gold-bearing rock of Steiglitz and Ballarat. Here in the picturesque gorges we can find examples of the strange fossils characteristic of beds of this age. The character of the rocks tilted, crushed and broken are so different from anything else in the neighbourhood of Geelong that they are worth a visit by all interested either in scenery or geology.

The Order of Succession of the Rocks.

Before turning to another subject we may as well summarise our results. We have taken the different sets of rocks, not in the order of their age but rather in that of their importance from the point of view of the scenery—the Barrabools, the coastal plain, the bluestone plain, and so on.

As regards their age, possibly the greenstones and granites are the oldest; we need not discuss it, but

the question needs settling. If they be the oldest, the next is the old series in the Moorabool Valley about Maude, near Lethbridge. Then come the Lake Sandstones of the Barrabools; still later succeeded the lignites or brown coals of Dean's Marsh, which are referred to in another chapter. Younger than these is the old bluestone at the base of the cliffs at Airey's and that forming the highest point of the Bellarine Hills. Then in ascending order come the rocks of the coastal plain, the bluestone plain, the freshwater limestones, the estuarine beds, and the dune rocks.

The Scenery of Geelong.

The scenery of a district is due to a combination of causes. The great moulding agency is the action of rain and streams, rasping and eating away at the surface and carrying mud and sand down hill to spread it over other levels. But there are other agencies at work.

Great fractures of the earth's crust often occur, and lower large blocks of land below the rest. This is the favourite agency which is invoked by people in a hurry. They see a valley and imagine some tremendous cataclysm has rent the ground, and then a river found its way into it. But most valleys have been carved out by the streams themselves. The valley generally is the effect of the stream and not its cause. The trough in which the Moorabool flows, the gorge at the paper mills, and the great valley below Queen's Bridge, are of this nature. The streams have simply rasped their way by the aid of

the sand and gravel they hurry along their beds. Geologists are consequently rather chary of invoking cataclysms.

But there are certain features about Geelong which are explicable on no other hypothesis. They have not as yet been fully worked out, and many points have not as yet been explained. There are some very interesting problems still awaiting solution in the neighbourhood, and they must be either lightly touched on, or omitted altogether, for in whatever way they are treated someone can find objections.

If we stand on the hill overlooking the valley of the Moorabool near Batesford, or near the railway viaduct, we see a level sheet of bluestone on both sides of the river, forming a great plain gashed by the river valley. The bluestone at each side is at the same height. If we take our stand on the Fyansford Hill and look westward, we see the bluestone plain about eighty feet below us across the river, with a gradual slope upwards towards Murgheboluc. The bluestone on both sides of the river lies on beds forming part of the coastal plain.

The only satisfactory explanation to be offered of this great difference of level is by calling in the agency of a north and south crack, or fault as geologists call it, which lowered the land to the westward. A cliff would thus be formed along the east side and along the edge of this cliff the river flowed, gradually cutting its present channel.

Another fault, and a much greater one, runs westward along the northern foot of the Barrabools. The two faults intersect about Queen's Park, and the

37.—View from the Barrabools, looking east. The bluestone plain in the middle distance has been lowered by a "fault" below the level of the hills on which the tall chimney at Fyansford stands. This hill is capped by the bluestone sheet. The Barwon River is in the foreground, and the Moorabool flows along the foot of the Fyansford Hill.

result was the tilting and lowering of the Murgheboluc plateau. The heavy quartz-gravels of Mercer's Hill perhaps show us the old course of the river. After the faulting the stream had to cut a new channel, and instead of continuing its easterly flow it turned south at Queen's Bridge and sawed its way through the coal rocks, and gave us the beautiful valley that occurs there. (See frontispiece.)

Although it has been necessary to invoke the aid of great fractures of the earth's crust, which lowered some parts and left others rising high above them in order to explain certain scenic features of the district, it must be borne in mind that such causes are not common ones. The great moulding agency, which carves the valleys, and rounds the hills, which here spreads a sandy plain and there carves another plain into hill and dale, is running water. The causes have acted gradually over long periods of time, and the chief results are due to this action and not to great catastrophes.

CHAPTER XV.

Round About Ballarat.

In the neighbourhood of Ballarat we can easily distinguish four types of country, or perhaps we might say five, for the flanks of the great volcanoes of Buninyong and Warrenheip are of a very different character from the western bluestone plain, in spite of the fact that both are of volcanic origin.

Standing on the cliff-like edge of this western plain in the neighbourhood of Sebastopol, we see that the level country is bounded to the eastward by an almost straight north-and-south line which holds its direction for a long distance. Looking eastward, we gaze over a long, narrow strip of country about four or five miles in width, and stretching far to the north and south, a country of low, winding ridges, separated by flat-bottomed gullies. Most of it has been stripped of its timber, but in some places we can still see the belts and patches of wooded land, the dark hues of the gum-tree foliage standing out in marked contrast to the white and red soil, that has been turned over by the tens of thousands of gold-miners who have dug below its surface. This is the Ballarat valley.

On the far side of this belt of country, away to the eastward, there rises up a long ridge, crowned by Warrenheip and Buninyong, and other less imposing rounded hills. Even from where we stand we can distinguish large patches of cultivation peeping forth from the tree-clad ranges.

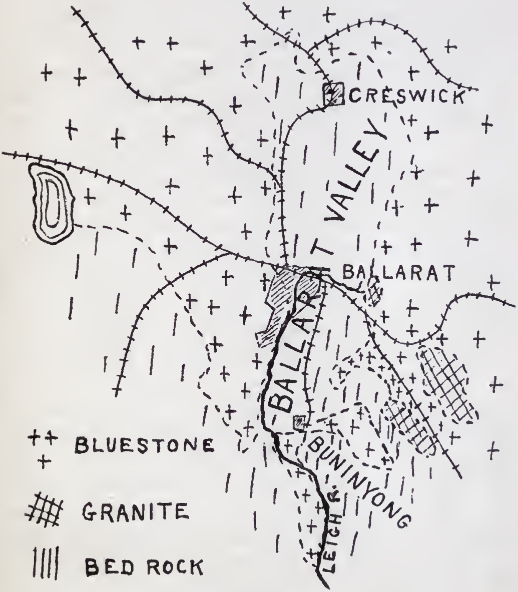
Thus we have three distinct areas of country—the western plain, the central valley, and the eastern hills. Let us take these three great belts in succession, and consider some of their characteristics and the causes that have brought them about.

THE CENTRAL VALLEY.

As we travel over this valley in different directions we notice great variations in the rocks that form its surface and in the vegetation that clothes it.

So greatly is it seamed by gullies with their small,

seldom-flowing streams, that at first one is apt to lose sight of the fact that the whole is but one broad valley. Down its centre, from beyond Black Hill in the



38.—Map showing the Ballarat Valley.

north through Mount Pleasant and the White Horse Ranges, stands up a long ridge, cut through here and there by streams hurrying west to join the Leigh.

This ridge divides the valley into two long strips which are, however, but imperfectly separated.

The Bed-Rock.

Black Hill, and indeed all the ridge, is composed of the old bed-rock of the district. Its original, horizontal layers, laid down as sheets of mud and sand on the floor of the ancient sea, have been folded and broken, so that they now stand on edge. The muds have been squeezed by ancient earth-movements, so that they have been turned into slates. They no longer split easily between the layers in which they were deposited, as hardened muds do, but split, so to speak, across the grain. This method of splitting is spoken of as slaty cleavage, and its presence in the Ballarat bed-rock has been the cause of a great deal of controversy among geologists and mining men.

The action of the weather on the slates of Ballarat has been more marked than is the case in drier districts, and their originally black or dark colours have been bleached white by the loss of the iron, which has been washed out of them by water sinking through the soil. The timber that the old bed-rock bears is generally of small size, and consists mainly of gums, which are clothed by a dark, rugged bark on trunk and branches alike. Probably it was from this fact that Black Hill derived its name.

The timber has disappeared, and the bleached slates make the hill stand up as a great gashed, white block that appears now to be very inappropriately named. Along the upper branches of the streams, that join to form the Leigh, we see, standing every here

and there, the square-sided blocks of slate and sandstone so characteristic of the bed-rock over large areas of the State. On the hills, where the rock is near the surface, the ground is strewn generally with small chips of slate, or else bars of sandstone stand up above the softer rocks that have washed away more quickly. The spoil-heaps of the Sebastopol mines show us that deep beneath the bluestone of the plain the same series of rocks is to be found.

But the great and most easily-applied test of the presence of the bed-rock near the surface is to be found in the dark-barked gums, whose main branches never appear white, as do those that grow on other ground. Far to the westward, beyond the Sebastopol plateau, our view is bounded by a well-wooded ridge of these old rocks, where lies the water-parting between streams flowing into the Leigh and those that drain into the great salt lake, Corangamite.

The Gravel-Hills and Flats.

The constant wearing of the old hills built of the bed-rock by streams and rain has broken up a good deal of the surface and spread out the harder and heavier fragments, which are chiefly pebbles of quartz and sandstane, as great banks of gravel. In these sheets of gravel the gold of the old bed-rock also collects. Some of the older banks now cap hills which, owing to their protection, have not been wasted away, while the rest of the country has been lowered by the ceaseless rasping of the sand-laden streams.

In other places fresh accumulations of sand, or sheets of once molten bluestone, have buried the old

valleys far below the present surface, and the investigation of the courses of these old buried stream-beds, or deep-leads as they are curiously called, is one of the difficulties that the miner has to face in his attempts to win the gold that they contain.

Along the course of the Buninyong railway line the gravel banks cover large tracts of country, and as the bed-rock from which they were formed does not seem to have contained much gold, very little of the metal has been concentrated in the gravels. In consequence of this the surface is almost undisturbed by the miner, and here we see a good deal of the particular vegetation that the beds naturally bear. Besides the ever-present gums, we find stray blackwoods and native cherries, but the most striking plants are undoubtedly the grass trees. Of these there are two kinds—the tall common species, with flower spikes rising to a height of six or seven feet; and the "lesser grass tree," with slender spikes, and rarely more than three feet high. These gravel banks in late spring are doubtless decked with many gaily-coloured flowers, among which the grass tree spikes rise like tall white wands.

As gravel banks are very porous, they drain well, and the vegetation of such banks suffers from lack of moisture. Plants which require a great deal of water will not grow on them, and we find plants that can withstand periods of drought. The grass trees are of this nature, and they may thus be taken as indicators of a dry soil.

As, however, the rainfall of Ballarat is fairly heavy, there is not the marked difference between soils

that hold water well and those that lose it readily that we find in districts where the rainfall is less.

Besides this fact, we must bear in mind another, and that is that local variations always occur, and we may find damp patches, even swamps or ponds, in the middle of such naturally dry areas as the gravel flats.

The Granites.

About the Gong Gong reservoirs we meet rocks of a different type. They have not been formed beneath water by materials carried down by streams, but have cooled and solidified from a melted state at great depths beneath the surface. The over-lying rock has been washed away during long ages of exposure, and the granite now appears at the surface. If we examine as fresh a piece of this rock as we can find, we see that it is composed of three kinds of minerals in about equal-sized grains. There are clear, glass-like grains of quartz, milk-white grains of felspar, and flakes of black mica, which we can bend to and fro with a pin-point.

In many places the granite is rotten, and may be broken up by the fingers. The quartz and mica are still visible and unchanged, but we cannot find the felspar at first, till we realise that it has turned to clay under the action of the weather.

Over the surface of the undecomposed, hard granite then we have in most places a greater or less thickness of decomposed rock, consisting of clay, in which are embedded numerous quartz-grains and mica flakes. The clay is fairly rich in plant-food, and ab-

sorbs and holds closely a good deal of the water that falls on it in the shape of rain. The plant-life is consequently more vigorous and varied than that found on the bed-rock or the gravel banks, and as the district is fairly moist, the trees grow in greater profusion than they do on the granites of drier regions, such as the You Yangs and other places near Geelong and Melbourne.

The gum-trees have smooth, white branches, and their trunks bear a grey fibrous bark differing from what we generally find on the trees of the bed-rock. The native cherry trees are magnificent specimens—tall, dark-green and shapely, while silver wattles and blackwoods abound. The imported trees of the reservoir reserve grow well, but, beautiful as they are, should we not as Australians ask for a more frequent planting of our native trees. There is more beauty and variety in the woodland on the hill-slope on the west side of the Gong Gong Creek than among the gloomy pines along the creek coming in from the east.

The Bluestone.

As was mentioned previously, there are in the neighbourhood of Ballarat two types of country covered by bluestone. The plateau about Sebastopol and all the great plain that spreads north from there past Lake Wendouree, and out to the west, has been covered by a flow of melted rock that filled the old valleys and spread over all in a vast level sheet. Beneath this, the miners tell us, are old hills and valleys formed of the bed-rock, and in the valleys are vast beds of gravel, just as we can see at the surface

in the great valley to the eastward. The melted rock cooled down and became hard and solid, and is now known as bluestone.

The plain spreads far to the westward, past Lake Burrumbeet, and away through South-Western Victoria, where we find one of the great volcanic areas of the world. The dense rock beneath the surface-soil does not allow water to soak in, and the vegetation of these plains is consequently that of an arid district. A few scattered gum-trees and sheoaks are about all the trees we find, and further west than Ballarat, on the open plains, even these are absent. But the rich though shallow soil carries a great growth of grass, and some day will undoubtedly be the great granary of the State.

On the eastern side of the great valley about Warrenheip, Yendon and on towards Buninyong the volcanic rocks are in many places of a different character from that of the plains. Bluestone sheets occur, but the greater amount consists of vast heaps of rock that has been blown to fragments by the explosions of the volcanoes. In ordinary language these fragments are spoken of as volcanic cinders, and as long as we remember that they are produced by the frothing and blowing to pieces of bluestone while it is still almost liquid, and have no relation to cinders in the ordinary sense of the word, the name does not much matter. Round about the vents of the volcanoes these cinders have been piled up to form great cones, such as those of Buninyong and Warrenheip. But between these great cones there are many smaller ones, and all have combined to spread the cinders and still finer volcanic

ash far over the country. The great crater of Buninyong can still be clearly traced, but its northern rim has been broken down so that the wall only stands intact along its southern side.

The composition of these ashes and cinders is the same as that of the bluestone, and from their de-

39.—The forest on the southern slope of Mount Buninyong. The porous cinder heap holds water well.

composition a rich soil is produced. As the underlying rock is porous and easily penetrated by rainwater, this sinks in and is preserved for the use of the plants, and a vigorous growth of trees is the result. On the southern flanks of Buninyong, where the moisture-laden south winds strike the lofty mountain side, the rainfall is heavy. The steep slope is

protected from the scorching north winds and from the heat of the midday sun, and a dense forest-growth is produced that to a certain extent recalls the straight-boled forests of the Otways. On the more level country, where the forest has been cleared away, the rich soil is cultivated for mile after mile, and the heavy crops of Warrenheip are famous throughout the State.

From these facts we can appreciate the effect of the nature of the subsoil on the growth of plants. It acts indirectly, not by reason of its richness or otherwise in plant food, but by the amount of water that it can store up against the dry weather and by the readiness with which it allows this stored-up water to circulate. For the best results to be attained there is not only the right amount of water, but there must be good subsoil drainage as well, or otherwise dissolved salts are too plentiful.

Geographical Changes.

The lava-sheets from the volcanic hills to the north, east and south once spread over perhaps the whole of the country about Ballarat. Time after time the volcanoes burst forth and the molten floods of rock flowed down the valleys. Then gravels and clays spread over them, and again a lava flood welled forth, and yet another layer of gravel was spread. This we know from what miners have told us of what they find underground.

At last the volcanic outbursts ceased, and a great layer of volcanic rocks—bluestone, cinders and ashes

—covered the country far and wide, and no trace of the bed-rock was to be seen. There was no valley where the present one lies, but a plain like that of Sebastopol spread from the foot of Warrenheip and of Buninyong. Then the streams began their work, and, some carrying their load of sand and gravel to the north and others to the south, they stripped the bluestone cover and laid the bed-rock bare, over what is now the Ballarat Valley. The great divide, or water-parting, of the State crosses this valley a few miles north of the city. There is no high ridge to mark its course, but it is probably not very far from where it was before the bluestone sheet so greatly modified the surface of the ground.

Through the last and greatest of the lava sheets the Leigh River then has worked its way. At one time the Gong Gong Creek, and the waters of the upper Leigh north-east of Black Hill, flowed down the great valley between Mount Pleasant and the highlands about Navigators, joining the present Leigh Valley somewhere to the west of Buninyong. Then the western branch, which flows along the flanks of the Sebastopol plateau, cut back its valleys to the north and east, and trapped the eastern streams, and the bulk of the water flowed, as it now does, between Black Hill and Mount Pleasant, and the wide valley east of the White Horse Ranges was left almost dry. This valley is larger than that of the Leigh near Sebastopol, and for a long time it must have carried the larger stream.

The lava that once covered perhaps the whole of the great Ballarat Valley was gradually removed,

and the great strip of bed-rock was laid bare. Over this the smaller streams have flowed, now here and now there. In one place they have cut away the surface and in another they have piled up banks of gravel that they were not strong enough to carry further. The surface of the land, while it stands above the sea, is ever changing. Hills are being worn down, valleys cut, and where the slope is less, the waste from higher lands is being spread out as beds of clay and sand and sheets of gravel. Over the surface of the great Ballarat Valley we can see Nature at her work carving and moulding the land, and we can see the changes going on, not here alone, but everywhere throughout the district, and everywhere where dry land is found.

Summary.

The five classes of country in the neighbourhood of Ballarat are, to a great extent, distinguishable by the vegetation that they bear. The plants tell us what the nature of the underlying rock is even when we are unable to see it at the surface. But the distinctions are not hard and fast, for local conditions may affect the result, and in some cases considerable care must be exercised before a decision is come to.

We have the bed-rock, with its rough, dark-barked gums; the gravel banks, with their strange grass trees; the granite, with smooth-barked, white-branched gums, lightwoods and cherries; the bluestone plain, with its dearth of trees and wealth of grass; and, lastly, the cinder-beds of Warrenheip and Buninyong,

with their dense forests of splendid timber and rich farm land.

One aspect we have left untouched, and that is the animal life. Each class of country has its own groups of beast and bird and insect. The chief reason for this is that plants form the prime food-stuff of animals. Even the flesh-eating ones feed on those which live on plants, and if there were no plants there would be no animals.

On the open bluestone plains we find no insects which live on the sap of trees or on the honey-yielding flowers of the gums, but we find instead grass-eating locusts and grasshoppers and the caterpillars, which, turning from their natural food, ravage our cereal crops.

These insects in their turn afforded food to the native turkey, native companion and the emu. We have allowed these great birds to be killed off almost entirely, but we still find the ground-lark and occasionally the ibis hard at work checking the ravages of these pests. In the dense timber of the cinder beds and the granite, honey-eating birds and insects abound. Pigeons, now, alas! too rare, find abundant food in the seeds of the wattles and other similar plants, while those gems of the forest, the blue wren and the flycatcher, revel in the varied richness of their insect food.

Naturalists find it convenient to divide the study of the earth and all that is therein into many compartments; some investigate the rocks, others the birds, other the plants, some a particular group of insects, and others the chemical nature of the soil. But

all the subdivisions are parts of one great whole, and to know one thoroughly means that we must know all. We can never tell when one small piece of knowledge will help us better to understand another that at first seems quite unrelated to it.

APPENDIX.

TABLE SHOWING THE GEOLOGICAL AGE OF THE ROCK SERIES MENTIONED.

Delta beds, alluvium of present rivers, sand-dunes, raised beaches, rain-wash from higher to lower ground	Recent.
Bluestone of the plains (Basalt, &c.) ...	Pliocene and Recent.
" Deep-leads "	Pliocene and older.
Rocks of the coastal plain, including the red-sands and gravels and the fossiliferous clays as at Mornington and near Hamilton ; limestones as at Waurn Ponds	Miocene to Eocene.
Macedon lavas	Tertiary.
Older bluestone (Basalt, &c.) ; lignites of Dean's Marsh and Altona Bay	Eocene.
Lake sandstones of the Wannon, Otways, Barrabools, and South Gippsland	Jurassic.
Glacial beds of Bacchus Marsh and Derrinal	Permo-carboniferous.
Granite of Melbourne dykes (Grano-diorite ?)	Devonian (?)
Macedon Dacite	Devonian.
Bed-rock of Melbourne	Silurian.
Bed-rock of Bendigo, Steiglitz, and Ballarat (?)	Ordovician.
Granite and greenstone (Diabase) of Geelong District	Palæozoic. (?)

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